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THE PLANT DISEASE REPORTER

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THE PLANT DISEASE SURVEY

Division of Mycology and Disease Survey
BUREAU OF PLANT INDUSTRY, SOILS, AND AGRICULTURAL ENGINEERING
AGRICULTURAL RESEARCH ADMINISTRATION
UNITED STATES DEPARTMENT OF AGRICULTURE

SUPPLEMENT 195

PLANT PATHOLOGICAL INVESTIGATION IN THE UNITED STATES

II

Supplement 195 September 15, 1950

The Plant Disease Reporter is issued as a service to plant pathologists throughout the United States. It contains reports, summaries, observations, and comments submitted voluntarily by qualified observers. These reports often are in the form of suggestions, queries, and opinions, frequently purely tentative, offered for consideration or discussion rather than as matters of established fact. In accepting and publishing this material the Division of Mycology and Disease Survey serves merely as an informational clearing house. It does not assume responsibility for the subject matter.

PLANT DISEASE REPORTER SUPPLEMENT

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THE PLANT DISEASE SURVEY
DIVISION OF MYCOLOGY AND DISEASE SURVEY

Plant Industry Station Beltsville, Maryland

PLANT PATHOLOGICAL INVESTIGATION IN THE UNITED STATES II

Plant Disease Reporter
Supplement 195 September 15, 1950

FOREWORD

Paul R. Miller

The first group of articles on plant disease investigation in the United States was published as Supplement 191. Comment has been very favorable and demand has exhausted our reserve supply. We hope this fact will be a partial recompense to the authors who worked so hard on their contributions.

Articles received since then are presented in this Supplement. Again we wish to thank the contributors for their cooperation in this project.

Others who are considering participation in this series should send us their articles in time for us to publish them before the end of this calendar year. After that time we cannot promise their publication.

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INVESTIGATIONS OF DISEASES OF FRUITS AND VEGETABLES IN TRANSIT, STORAGE AND AT THE MARKET, WITHIN THE UNITED STATES DEPARTMENT OF AGRICULTURE

Harold T. Cook

HISTORY

Since 1930, investigations of the post-harvest diseases of fruits and vegetables have been centered in the Handling, Transportation, Storage and Market Disease Section of the Division of Fruit and Vegetable Crops and Diseases. Previously, they were conducted in various subdivisions of the Department, such as the Office of Pomological Investigations, the Bureau of Markets, and the Office of Cotton, Truck and Forage Crop Disease Investigations.

The headquarters of the present research is located at the Bureau of Plant Industry, Soils, and Agricultural Engineering Station at Beltsville, Maryland. The research is conducted at that station, and at field stations located at Fresno and Pomona, California; Wenatchee, Washington; Harlingen, Texas; Meridian, Mississippi; East Grand Forks, Minnesota; and Orlando, Florida; at market pathology laboratories in Chicago, Illinois, and New York City; at various shipping points; and during shipment, in trains, ships, planes, and trucks.

Interest in the problem of supplying the cities with fresh fruits and vegetables is not new. In the report of the Commissioner of Patents for the year 1861, page 368, Professor L. C. Loomis writes as follows -- "Now it is to be observed that but a small portion of the ordinary supplies of our large cities is in a proper condition when offered in market. The desire of securing the high prices of the earliest products induces the gathering of the first growth while yet unripe, and of that which remains till fully matured the succulent fruits and vegetables commence decay before reaching the termination of the distances large quantities are transported."

In the report of the Commissioner of Agriculture for the year 1869, page 445, a correspondent in California wrote -- "Shipping fruit east has been a failure thus far. This result is owing entirely to want of knowledge on the subject. Most of the fruit shipped has been picked while green, and being poorly packed, has been lost before it reached the eastern markets. There can be no question that our apricots, cherries, pomegranates, pears, and grapes can be placed in New York in good condition and command high prices, but the science of picking and packing must first be understood."

In 1900, Dr. William A. Taylor, who later became Chief of the Bureau of Plant Industry, demonstrated that by means of proper refrigeration it was possible to ship fresh apples and oranges long distances and prolong their market seaason. By this means, he maintained a continuous exhibit of oranges from California and apples from 17 different States at the Paris Exposition (1).

G. Harold Powell, who succeeded Dr. Taylor in charge of the Fruit Transportation and Storage Investigations, studied the actual handling and transportation of carload lots of oranges from California to the eastern markets. His report on these studies in 1908 in a bulletin (124) entitled "The Decay of Oranges While in Transit from California" was an outstanding contribution. As a result of these studies, the chief hazard to the successful marketing of citrus was removed and the long-distance shipment of these fruits became practicable.

About the time that Powell was working on citrus, L. L. Harter made studies of the causes of decay of cabbage in storage and published his results in a circular (71) entitled "The Decay of Cabbage in Storage: Its Cause and Prevention".

In 1915, H. J. Ramsey published a bulletin (144) on his investigations of the effect of careful handling, precooling, and refrigeration in transit on the development of decay in red raspberries shipped from the Puyallup Valley of Washington. This was followed by a preliminary report by F. C. Meier (101) on watermelon stem-end rot in 1917, by a series of papers on strawberry transit diseases by Neil E. Stevens and associates (170, 174, 176) and reports by L. A. Hawkins (80, 81) on his investigations of the cause and prevention of potato leak in 1916 and 1917.

Recognition of the need for special work on market diseases of fruits and vegetables led to the establishment by the Bureau of Markets of market disease laboratories in New York City and Chicago in 1917. Plant Pathologists in these laboratories studied the market diseases, assisted in instructing the inspectors of the newly organized Food Products Inspection Service, and diagnosed plant diseases found in market consignments.

The establishment of the Inspection Service and market disease laboratories gave a great impetus to the study of diseases that affect fruits and vegetables after harvest. In 1919, G. K. K. Link and M. W. Gardner of the Chicago laboratory published a paper (93) in which they reported on the results of the first year's study on market pathology of truck crops. They pointed out that losses in transit were particularly lamentable because of the value of the time and labor concentrated in the harvested product en route to market. A survey of losses in some of the larger markets of the country showed a minimum loss of $1,250,000 in 1918 to watermelon shipments from four States; loss of hundreds of cars of California grapes from decay caused by Botrytis, Penicillium, and Aspergillus; that 15 to 25 percent losses in Cuban pineapples from Thielaviopsis rot were accepted as a matter of course; and that green vegetables, especially lettuce and beans, usually had to be sorted and reconditioned upon arrival in the markets.

In 1948, Wiant and Bratley (189) published an analysis of over 117,000 inspection certificates issued by Federal Produce Inspectors at New York City between 1935 and 1942. Fourteen different fruits and thirty-one different vegetables were covered by the certificates. The analysis showed that an average of 2.1 percent of all fruit and 3.8 percent of all vegetables were affected by decay or other breakdown.

Soon after the establishment of the market disease laboratories G. K. K. Link and M. W. Gardner published a "Handbook of the Diseases of Vegetables Occurring Under Market, Storage, and Transit Conditions" (92), and D. H. Rose and O. F. Burger published a handbook "Diseases of Fruits Occurring Under Transit, Storage, and Market Conditions" (154). These handbooks were designed primarily to aid the inspectors of the Food Products Inspection Service and their distribution was limited. They were the forerunners of the very popular and useful series of nine U. S. Department of Agriculture Miscellaneous Publications on Market Diseases of Fruits and Vegetables (96, 138, 141, 142, 143, 151, 152, 153, 156) that were published over the period 1932 to 1944 and that are now being revised. This series covered the market diseases of apples, pears, and quinces; citrus and other subtropical fruits; grapes and other small fruits; peaches, plums, cherries and other stone fruits; asparagus, onions, beans, peas, carrots, celery, and related vegetables; beets, endive, escarole, globe artichokes, lettuce, rhubarb, spinach, swiss chard, and sweetpotatoes; crucifers and cucurbits; potatoes; and tomatoes, peppers, and eggplants. They contain numerous illustrations, many in color, of the diseases as they appear in the market.

In 1918, the Bureau of Markets issued a bulletin (35) entitled "Suitable Storage Conditions for Certain Perishable Food Products". In this bulletin directions were given for the proper storage conditions for fruits, vegetables, dairy and poultry products. This bulletin was superseded as far as fresh fruits and vegetables were concerned in 1933 by a circular (160) by Rose, Wright, and Whiteman entitled "The Commercial Storage of Fruits, Vegetables and Florists' Stocks". This publication has gone through several revisions, the last in 1949, and is generally recognized as the standard guide on the storage of fruits and vegetables.

In 1922, the work of the market disease laboratories was transferred to the Bureau of Plant Industry where it could be coordinated better with the other research on storage and transit of fruits and vegetables. However, provision was made for the pathologists of these laboratories to continue to serve as instructors and consultants to the Food Products Inspection Service.

RESEARCH ON POST HARVEST DISEASES OF FRUITS

APPLES AND PEARS: D. H. Rose (146) analyzed the apple inspection certificates for the period November 1917 to July 1921 and found that during the four-year period blue mold occurred more commonly than any other disease. In the boxed apples, scald was second and other decay third in importance, while in the barreled fruit other decay was second, and black rot third.

Apple scald, because of its importance in storage and on the market, was the subject of many of the early investigations. The first definite contribution was made by Powell and Fulton (123) in 1903. They found that immature and poorly-colored fruit scalded worse than mature, well-colored fruit, that more scald occurred at 36° F. or higher than at 31° to 32°, and that delays in storing caused more scald. The work of Brooks, Cooley, and Fisher (11, 16, 17) demonstrated the physiological nature of scald and showed that it could be prevented by air circulation and by wrapping the fruit in oiled paper. Further work by the same authors (14, 19) perfected the oiled wraps or shredded oiled paper method of preventing scald to such a degree that it soon came into general commercial use. Recently Schomer and Marth (163) reported that treating fruit with growth-regulating substances reduced the amount of scald.

In 1917, Brooks and Cooley (12) published the results of several years investigations on temperature relations of apple rot fungi. They found that low temperatures had more effect on the growth of fungi on fruit during the initial incubation stages than after the fungus became established. These results showed the importance of promptly and rapidly lowering the temperature of fruit in storage. Haller and Lutz (67) in 1941 reported 50 percent greater decay of apples at 36° than at 32° F. in Potomac River Valley storages.

Fisher (50), in 1925, described the fruit rot stage of the newly described perennial canker disease of apple, and in subsequent papers Fisher (54) and Fisher and Reeves (55) reported on the methods of infection and the importance of rain in dissemination of the organism. Miller (105), in 1932, published on his physiological studies on the perennial canker and anthracnose fungi (Gloeosporium perennans and Neofabraea malicortis) and the rots caused by them.

Brooks and Fisher (20) reported in 1918 that the development of bitter pit and Jonathan spot in storage was influenced by irrigation practices and time of picking.

Rose and Lindegren (158) in 1925 reported on their study of the occurrence of Phytophthora rot as a market disease of pears and apples from several States.

Soft scald and soggy breakdown of apples and pears were the subject of a series of papers beginning in 1920 (18, 22, 61, 62, 63, 66, 68, 69, 70, 106), but no definite control measures have ever been found. The physiological studies and tests on methods of handling, however, have indicated ways in which the disorder may be partially alleviated.

Cooley and Crenshaw (34), in 1931, introduced the use of copper impregnated fruit wraps for the control of gray mold or Botrytis rot of pears. The use of copper-treated wraps is now a general commercial practice and has resulted in important monetary savings.

Extensive studies were made by Bratley (5, 6) on the development of apple scab in storage. He found that scab lesions enlarged in storage and that new lesions resulting from late-season infections may develop during storage on apples that showed no scab when harvested.

When chemical solvents for the removal of spray residue were first employed in the commercial fruit washing operations in the Pacific Northwest, chemical injuries sometimes resulted which were often followed by various kinds of fungus rot. Studies on the effect of the cleaning methods on the keeping quality of apples and pears were conducted, the results of which were published in a series of papers from 1927 to 1931 (38, 39, 52, 53, 56). Information furnished by these investigations made it possible to advise packers how to remove spray residue without injuring the fruit. Recently the use of sodium chlororthophenyl phenol in the wash water for control of various fruit rots has come into commercial use as the result of experimental work by English, Wright, and Smith (44, 48).

Extensive studies have been conducted by English, Smith, Wright, and Ryall on the effect of handling methods and bruises on the development of decay. The results to date have shown that bruises, open lenticels, and washing injuries are the principal courts of infection and that contaminated wash water is an important source of blue mold and other spores (47, 198).

Schomer and McColloch (162) in 1948 reported on the results of their studies on the use of ozone to prevent decay of apples in storage. They found that ozone did not prevent decay or reduce infection of wounds although it did retard the rate of enlargement of infected areas. Fungus colonies on package surfaces were very resistant and were not killed by continuous exposure for 5 months to an atmosphere containing 3.25 p.p.m. of ozone. Fruit was injured and the flavor impaired by the above concentration.

CITRUS: The storage and transportation diseases of citrus fruits have been under investigation since the earliest days of the Bureau of Plant Industry and are being conducted at the present time in Florida, Texas, California, and the market disease laboratories at Chicago and New York.

The early work of Powell (124) on decay of California oranges in transit has already been cited. At about the same time that his work was being conducted with California oranges, similar work by Tenney, Stubenrauch, and others (178, 179) was under way in Florida. These workers found that much of the decay was caused by infection in mechanical injuries from rough handling during the harvesting and packing operations.

Experiments by Fulton and Bowman (58) in Florida and by Barger and Hawkins (3) in California, reported in 1924 and 1925, demonstrated the effectiveness of borax in the wash water for the control of citrus decay. Winston (192) conducted further tests on the borax treatment, the results of which were published in 1935. The results of these investigations form the basis for the borax treatment of citrus that is now used in many packing houses.

Barger cooperated with H. S. Fawcett of the University of California in a study of the relation of temperature to growth of Penicillium italicum and P. digitatum in culture and in the fruit. The results of these tests, which were published in 1927 (49), showed that both fungi grew best and caused more rapid decay at temperatures between 66.8° and 80.6° F. and that P. digitatum was retarded more than P. italicum by higher or lower temperatures.

Fulton and Coblentz (60), in 1929, reported that an estimated 998 out of 1000 spores of Penicillium digatatum were killed by a 45-second exposure to ultraviolet rays. However, holding tests with irradiated oranges showed that the treatment only moderately retarded decay. Failure to obtain better control of infection was attributed to inability of the rays to penetrate much, if any, below the surface and to shading of some of the spores.

Miller, Winston, and Fisher (107) in experiments reported in 1940 demonstrated that oranges and grapefruits affected with Penicillium digitatum evolve more ethylene than normal fruit. They also obtained positive tests for ethylene with the fungus in pure culture. These results were significant, since they indicated that the presence of decaying fruits in a storage room or container may, by the evolution of ethylene, hasten senescence in other fruits.

Stem-end rot caused by Phomopsis citri and Diplodia natalensis is a very serious post-harvest disease of citrus in Florida, the Gulf Coast States and Texas. Winston, Fulton, and Bowman (195) in 1923 showed that the stem-end rot fungi first gain a foothold somewhere on the stem or button and that disbuttoning would prevent the disease. They showed that the gassing treatment used for degreening the fruit loosened the buttons so that they could be removed easily without damaging the fruit. Winston (193) in 1936 published data showing that pulled grapefruit is less rapidly affected by stem-end rot than clipped grapefruit. He recommended harvesting by pulling, especially for fruit intended for storage or export.

Fulton and Bowman (59) reported in 1927 that the results of six seasons' tests showed that citrus fruit from old trees in Florida kept better if the trees were sprayed once between April 15 and May 5 with 3-3-50 bordeaux mixture. Phomopsis type stem-end rot was reduced by one half or more and Diplodia stem-end rot by a fifth. Blue mold rot was not affected.

During the last ten years a considerable amount of work has been done on developing new chemical treatments for stem-end rot control. Brooks (9) studied various treatments in relation to the ethylene gas degreening treatment. He concluded that borax was the most effective disinfectant, provided it was applied before the ethylene treatment. As an after-ethylene treatment sodium ortho-phenylphenate was more effective. Miller, Winston, and Meckstroth (108) found that treating with a 2 percent solution of sodium ortho-phenylphenate at 110° F. for 2 minutes controlled citrus decay but injured the rind. By adding 1 part by weight of commercial formaldehyde (37%) for 4.5 parts of the fungicide they were able to practically eliminate the injury.

Ryall (65, 161) in cooperative investigations with the Texas Agricultural Experiment Station, tested a number of disinfectants and found that sodium ortho-phenylphenate and sodium metaborate were effective against stem-end rot. They reported further reduction in decay by wrapping the fruit in diphenyl-impregnated tissue wraps and by treatment with nitrogen trichloride gas. Ramsey, Smith, and Heiberg (136) and Heiberg and Ramsey (82) investigated the fungistatic action of diphenyl and found that it was very effective against the stem-end rot and blue and green mold fungi. The material is now becoming rather widely used for impregnating the tissue fruit wraps and box liners.

Childs and Siegler (30, 31, 32), Siegler and Childs (166), Winston (194), and Winston, Meckstroth, Roberts, and Cubbedge (196) have reported on screening tests with hundreds of chemicals for stem-end rot control. A number of chemicals, such as thiourea, have been found to give excellent control of the disease, but have proven toxic in animal tests. A number of other effective materials, such as 2-amino-pyridine, are still being tested for animal toxicity.

Brooks and McColloch (23, 24) in 1936 and 1937 published the results of their investigations of physiological storage diseases of grapefruit and lemons, and in 1946 Harvey (79) published on the relation of Alternaria decay to the physiological condition of lemons as affected by maturity and storage conditions.

CRANBERRIES: The storage diseases of cranberries have been extensively studied by C. L. Shear, N. E. Stevens, and H. F. Bain. This work has been summarized in their bulletin, "Fungous Diseases of the Cultivated Cranberry" (165), which contains an excellent bibliography.

FIGS: Brooks and McColloch (25) studied the spotting of figs on the market and reported that atmospheres containing 23 percent or more carbon dioxide give as good control as immediate storage at 32° F.

GRAPES: Mann (99) studied the handling of California table grapes and in 1929 reported on the importance of careful handling in picking, packing, and shipping grapes to avoid excessive decay, shattering, and raisining. Asbury, Bratley, and Barger (2) in 1940 reported that raisining of California grapes increased up to 10.3 percent during the 10- to 14-day transit period to New York. Most of the increase was due to grapes that were somewhat shriveled or brown in color when shipped.

The use of sulfur dioxide for the control of Botrytis and Penicillium decay of grapes has received considerable attention at the Fresno Station. The results of these studies are presented in a series of papers by W. T. Pentzer, C. E. Asbury, K. C. Hammer, and W. R. Barger (114, 115, 116, 117, 118, 119, 120). The tolerance of different varieties to sulfur dioxide gas and the effect of fumigation on the respiration of the fruit was determined. A method was developed for the slow release of SO_2 within the package. A study was made on the toxicity of SO_2 to Botrytis spores and its effect on infection.

PINEAPPLES: Bratley and Mason (7) in studies with Puerto Rican pineapples demonstrated that much of the decay caused by Ceratostomella paradoxa in transit to New York could be controlled by painting the freshly cut butts with a tincture of benzoic acid at the time of harvesting and packing.

Smith and Ramsey (169) recently reported the occurrence of bacterial fruitlet rot on pineapples that had been shipped by air from Mexico to Chicago. This is the first report of this disease in North America.

STONE FRUITS: Ramsey (145) in 1916 stated that the successful shipment of cherries and fresh prunes is dependent on the elimination of decay in transit and on the market. For the control of decay he recommended proper handling to avoid injuries, orchard sanitation, prompt loading and prompt precooling. These basic principles have been confirmed by further work. Brooks and Fisher (21), in 1921, reported that by means of orchard spraying they reduced brown rot on cherries in transit from 24.3 to 6.4 percent and brown rot on prunes from 28 to 7.1 percent. Brooks and Cooley (13) in the same year reported that prompt cooling resulted in better control of stone fruit rots than was obtained if cooling was delayed for one day. The same authors in 1928 (15) showed that greater infection with brown rot and *Rhizopus* rot occurred if the fruit was wounded.

Rose (147), in 1924, published a bulletin on "Diseases of Stone Fruits on the Market", and in 1933 Brooks (8) published a circular "Spoilage of Stone Fruits in the Market".

A considerable amount of work has been done by Department workers on the use of carbon dioxide for the storage of stone fruits. Brooks and others (27) showed that carbon dioxide gas was as effective in retarding the softening and decay of certain fruits and vegetables as was precooling them, but that prolonged exposure to atmospheres containing a high percentage of the gas caused objectionable changes in flavor. Brooks, Bratley, and McColloch (10) experimented with short-period carbon dioxide storage for 40 different fruits and vegetables. They obtained favorable results with plums, peaches, Bartlett pears, raspberries, figs, grapefruit, oranges, and sweet cherries. In general, the short-period gas treatment was as effective in retarding decay and maintaining firmness of the fruit as immediate storage at 32° F. and did not impair the flavor. Gerhardt and Ryall (64) controlled fungus decay of sweet cherries for 17 to 20 days in storage at 45° F. with 25 percent carbon dioxide, and the cherries were firmer, brighter, and fresher than those stored in ordinary air at 32°. English and Gerhardt (45), in simulated transportation tests, showed that concentrations within the range encountered in commercial shipments would definitely inhibit brown rot and *Penicillium* decay. As a result of the above experiments and actual transportation tests the use of carbon dioxide as a supplement to ordinary refrigeration has come into general use by Pacific Coast cherry shippers, and approximately 375,000 pounds of dry ice are used annually for this purpose. The better quality fruit from carbon dioxide treated cars often commands a higher price, amounting in some cases to $300 additional per car.

Ultraviolet light treatment for the control of decay of stone fruits was tested at the Fresno, California, and Wenatchee, Washington, laboratories. English and Gerhardt (46), at Wenatchee, found that although ultraviolet light was toxic to spores it did not control natural decay of cherries even when the period of exposure was up to 25 times longer than the usual commercial treatment. Most spores of *Penicillium expansum* were killed in 30 seconds but only a few *Alternaria* spores were destroyed by a 5-minute exposure. They concluded that the failure to obtain control was due partly to the spores becoming lodged in ruptures of the skin where the ultraviolet light could not reach them. Dewey and Pentzer (37) at Fresno also reported failure of ultraviolet light to control decay in peaches, nectarines, and plums. The results obtained with stone fruits were similar to those reported by Fulton and Coblentz (60) with citrus in 1929.

STRAWBERRIES: Rose (149) in 1926 and Stevens (172) in 1932 published an analysis of market diseases of strawberries based on market inspection certificates. Rose reported that during the 7-year period 1919 through 1925 the average percentage of rot for all cars inspected was 5.8, and that 58 percent of the rot was caused by *Rhizopus*. Stevens reported that the losses during the period 1926 to 1930 showed a decided decrease in both *Rhizopus* and brown rot. He attributed much of the decrease to improved refrigeration and handling methods.

Stevens (170), Stevens and Wilcox (80, 176), and Stevens and Hawkins (174) published a series of papers in 1917 and 1918 on the nature of the *Rhizopus* and *Botrytis* rots and on *Rhizopus* rots in transit. They stated that the best control of *Rhizopus* was obtained by careful handling and keeping the berries at a low temperature.

Stevens and Chivers (173) reported that their experimental results indicated that the keeping quality of strawberries was not lowered by picking while wet. They advised against attempting to dry the berries before packing. Stevens (171) had previously reported that strawberries kept better if picked early in the morning while cool even though they were wet.

In 1924 Rose (148) described "leather rot" of strawberries caused by *Phytophthora cactorum*, and Dodge and Stevens (51) described "hard brown rot" caused by *Rhizoctonia solani* and "tan rot" caused by *Pezizella lythri*.

Fisher and Lutz (51), in 1939, reported that in their transportation tests decay increased as the temperatures increased from 40° to 80° F. Rose and Gorman (157) recommended that strawberries be precooled to 40° F. or slightly lower before shipment.

RESEARCH ON POST-HARVEST DISEASES OF VEGETABLES

BEANS: Ramsey (128) investigated the relation of four species of *Sclerotinia* to decay in beans and other vegetables under transit and market conditions. Harter and Whitney (77), in 1927, reported on nesting in transit caused by *Pythium aphanidermatum*. They stated that it was very common on beans in transit during the warmer months of the shipping season. Lauritzen, Harter, and Whitney (90) in 1933 published the results of their rather extensive investigations on the effect of environmental factors on the development of diseases that occur in transit. Harter and Zaumeyer (78) discussed the various transit and market diseases of beans in a monograph published in 1944. Brooks and McColloch (26) investigated the cause of spotting and stickiness of shelled green lima beans. They found that the spotting was caused by *Cladosporium herbarum* and the stickiness was due to various species of bacteria. Washing the pods with a chlorinated lime solution before shelling gave good commercial control.

CARROTS: Meier, Drechsler, and Eddy (102), in 1922, described the black rot disease of carrots, caused by *Alternaria radicina*, which was responsible for serious losses on the New York market during the winter of 1918-1919. Lauritzen (85) made a further study on the relation of black rot to the storage of carrots in which he determined the method of infection, susceptibility of different varieties, and temperature relations.

Ramsey (127), in 1924, described a new species of *Sclerotinia* as the cause of decay of carrots on the market.

In 1932, Lauritzen (87) reported on his extensive investigations of storage and transit diseases of carrots, including *Sclerotinia* soft rot, *Rhizopus* soft rot, bacterial soft rot, and *Botrytis* rot.

Ramsey (130), in 1934, reported a *Rhizoctonia* rot on New York carrots and, in 1949, Ramsey and Smith (140) reported serious losses from this disease on carrots in Chicago storages.

CRUCIFERS: Reference has already been made to Harter's early work on decay of cabbage in storage (71). Ramsey (131) found that stored cabbage is sometimes seriously affected with downy mildew, and Drechsler (42) described a *Pythium* rot of cabbage on the market. Lauritzen (86) described a *Rhizoctonia* rot of turnips in storage. He reported that losses could be reduced by storing at a temperature of 0 to 2° C. and 90 percent relative humidity.

CUCURBITS: Reference has already been made to the paper by Meier (101) in 1916 on watermelon stem-end rot. In 1917, Orton (113) described the bluestone and starch paste stem treatment for control of stem-end rot in transit.

Smith and Bryan (167) and Carsner (29) published on the bacterial nature of the angular leaf spot of cucumbers in 1915 and 1918. Meier and Link (103) in 1922 stated that fruit spots caused by this disease could develop in transit following infection during the harvesting and packing operations.

Drechsler (41), in 1925, described the cottony leak of cucumbers, which occurs on cucumbers in the market. In 1940, Wiant and Tucker (191) described a market rot of Winter Queen watermelons caused by *Phytophthora capsici*.

Wiant (188) made an extensive study of the *Mycosphaerella* black rot of cucurbits during the period 1938 to 1942, the results of which were published in 1945. In 1937 and 1938, Wiant published two technical bulletins (185, 186) on market and storage diseases of cantaloups and honeydew melons which covered the results of six years' investigations.

Pentzer, Wiant and MacGillivray (121), in 1940, published a comprehensive report of their extensive investigations on market quality and condition of California cantaloups as influenced by maturity, handling, and precooling.

EGGPLANTS: Harter (72), in 1914, described the *Phomopsis* fruit rot, which is the most common and destructive decay of eggplants found on the market. Drechsler (43), in 1926, described the cottony leak caused by *Pythium*, which affects eggplant fruit on the market.

GLOBE ARTICHOKE: Link, Ramsey, and Bailey (97), in 1924, published a report on their extensive investigations of the *Botrytis* rot of globe artichokes, which causes serious losses in transit.

ONIONS: Walker (180, 181), in 1925 and 1926, published the results of his investigations on *Botrytis* neck rot of onions. He determined the relation of temperature to infection and progress of decay and also showed that desiccation of the neck tissues by artificial curing reduced the losses in storage.

Walker and Tims (182), in 1924, and Link and Bailey (91), in 1925, published on their studies of Fusarium bulb rot of onion, which is important in storage and in transit.

Ramsey and Butler (135) described the injury caused by exposure to ammonia. In 1930, Ramsey (182) published a circular describing the blemishes and discolorations of market onions caused by chemicals, sunlight, and fungi. Ramsey, Heiberg, and Wiant (91) published the results of their studies on Diplodia rot of onions in 1946.

POTATOES: Storage, market, and transit diseases of potatoes have been the subject of extensive investigations by the Bureau of Plant Industry. Orton (111) as early as 1913, and Shapovalov and Link (164), in 1924, published farmers' bulletins on tuber diseases in which they gave directions on proper temperatures in transit and in storage. Reference has already been made to the papers by Hawkins (80, 81) on potato leak.

Orton (112), in 1913, published a paper on the powdery rot of potatoes, in which he warned the growers of the need for care in digging and handling so as to avoid bruising or wounding the potatoes. The results of further investigations on the Fusarium storage rots were published by Carpenter (28), in 1915, Pratt (125), in 1916, and Weiss, Lauritzen, and Brierly (184), in 1928.

Link and Meier (95), in 1922, published a circular on late blight tuber rot in which they discussed the effect of temperature on development of tuber rot in storage and in transit. Cook and Lutz (33) studied the relation of rainfall to time of development of late blight in the field and to the importance of tuber rot in storage at Grand Forks, North Dakota, in 1948. They found that late blight tuber rot is unlikely to be important in storage in seasons when blight occurs early and dry weather prevails during the late part of the growing season and at harvest.

Meier and Link (104), in 1923, published a circular on potato brown rot in which they discussed the development of the disease in storage and methods of controlling it.

Rose and Schomer (159) showed that exposure of the potatoes to heat injury and desiccation made them susceptible to bacterial soft rot. Smith and Ramsey (168) described bacterial lenticel infection, which they said was especially serious on early potatoes grown in wet, heavy soils. Dewey and Barger (36) showed that lenticel infection may also occur in potatoes washed in deep vats as a result of the hydrostatic pressure due to deep submersion forcing the bacteria into the lenticels, and that mechanical injuries are also courts of infection.

Wiant (187), in 1945, published on his investigations of the internal black spot of potatoes. He found that black spot followed mechanical injury to potatoes that had already been submitted to pressure bruising while in storage, and that it was especially apt to develop when the injury occurred while the potatoes were cold.

Wright (197), in 1939, published a very comprehensive bulletin on bruising, freezing, and chemical injuries of potatoes in transit.

Barger, Ramsey, Perry, and MacGillivray (4), in 1942, reported on shipping tests with new potatoes from Kern County, California; and in 1944, Ramsey, Lutz, Werner and Edgar (139) reported on shipping tests with washed early potatoes from Nebraska.

Rose (150), in 1946, published a very comprehensive bulletin on handling and shipping early potatoes. Rose and Cook (155), in 1949, published a review of the literature since 1938 on storage and transit diseases of potatoes.

SWEETPOTATOES: Sweetpotato storage diseases were extensively studied, principally by Harter, Weimer, and Lauritzen. Harter and Weimer (75) summarized the results of these studies in a monograph in 1929. Since this monograph contains an excellent bibliography only a few of the individual papers will be cited here.

Harter and Field (74) published the results of their studies on dry rot caused by Diaporthe batatatis in 1913, and in 1916 Harter (73) published a bulletin on sweetpotato diseases which had a section on storage rots and their control. This was followed in 1918 by a paper by Harter, Weimer and Adams (76) on sweetpotato storage rots.

During the period 1921 through 1926, Harter, Weimer, and Lauritzen published numerous papers on Rhizopus rot, which is the most serious disease of sweetpotatoes in storage. These papers covered a study of the different species of Rhizopus that affect sweetpotatoes, the effect of temperature and humidity on growth and infection, the production of enzymes and the physiology of parasitism. Citations to these papers may be found in the monograph (75) by Harter and Weimer.

In 1935, Lauritzen (88) published a paper on further studies on factors affecting infection and decay by various storage rot fungi.

Lutz (98), in 1945, reported on chilling injury of cured and non-cured Puerto Rico sweetpotatoes.

In cooperative experiments with the Louisiana Agricultural Experiment Station, Martin, Lutz, and Ramsey (100) tested the effectiveness of dip treatments for the control of black rot in transit on washed sweetpotatoes. Dipping the potatoes in a borax solution gave promising control, but a wax emulsion containing sodium ortho-phenylphenate was not effective. Kushman and Cooley (84) reported in 1949 that subjecting infected sweetpotatoes to 110° F. for one day and then curing at 85° and 80 percent humidity prevented development of black rot in storage.

SPINACH: Wiant, Ivanoff, and Stevenson (190), in 1939, described the white-rust disease, caused by *Albugo occidentalis*, which Wiant found on Texas spinach on the New York market in 1937.

Friedman (57), in 1950, reported that bacterial soft rot is the principal cause of decay in prepackaged spinach. Increased drying by centrifuging reduced decay, but the best control was obtained by refrigeration.

TOMATOES: Tomatoes are especially subject to decay in transit and on the market, and they have, therefore, been the subject of much study. Stevens and Nance (175) analyzed the market inspection certificates issued on tomatoes from five different States and Mexico to determine the diseases that cause spoilage in transit. Diseases listed on the certificates were *Rhizopus* (*Rhizopus nigricans*), *Phoma* (*Phoma destructiva*), bacterial soft rot (*Bacillus carotovorus* and others), soil rot (*Corticium vagum*), blossom end rot (physiological), buckeye (*Phytophthora terrestris*), anthracnose (*Colletotrichum phomoides*), *Alternaria*, *Fusarium*, late blight (*Phytophthora infestans*), and nailhead (*Macrosporium* spp.). *Rhizopus* was the most important, *Phoma* rot was second, and bacterial soft rots were third.

Jamieson (83), in 1915, published the results of investigations showing that *Phoma destructiva* was an active wound parasite on green or ripe tomato fruit. Link and Meier (94) stated in a circular published in 1922 that the fungus does not grow above 90° F. or below 42°. Fruit from infected fields not showing any signs of the disease when packed developed *Phoma* spots in 4 or 5 days in transit or in ripening rooms. Nightingale and Ramsey (109) studied the development of *Phoma* rot in test shipments from Florida. They found that tomatoes that apparently were sound when packed showed *Phoma* lesions on arrival at market and that the lesions enlarged more rapidly as the fruit became riper.

Ramsey and Bailey (133) made field, transit, and storage studies of nailhead spot of Florida tomatoes from 1925 to 1927. Their studies showed that there may be an appreciable increase in number of spots and percentage of infected fruits during transit and storage.

Pritchard and Porte (126), in 1923, described a watery soft rot caused by *Oospora lactis parasitica*. The rot was reduced considerably by washing the fruit with an aqueous solution of chloride of lime (1:40) or formaldehyde (1:240). Ramsey (132), in 1935, described the *Pleospora* rot of tomato that had caused considerable damage to California tomatoes during the three preceding years.

In 1931, Ramsey and Bailey (134) published the results of their studies on late blight rot in transit and at the market. They found that the blight lesions increased 1 to 1 1/2 inches in diameter during six days in transit. They obtained some control by immersing the fruit for two minutes in a formaldehyde solution (1:300).

Nightingale and Ramsey (110), in 1936, published a paper on their extensive studies on the temperature relations of nine different fungi that cause tomato fruit rots. Growth rate in culture, infection, and development of decay were studied.

Porte (122), in 1934, tested various chemical washes and found that the chemical treatments reduced the number of decayed fruits by as much as 29 to 59.5 percent.

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U. S. DEPARTMENT OF AGRICULTURE, DIVISION OF FRUITS AND VEGETABLE CROPS AND DISEASES, BUREAU OF PLANT INDUSTRY, SOILS, AND AGRICULTURAL ENGINEERING

VEGETABLE DISEASE INVESTIGATIONS IN THE UNITED STATES DEPARTMENT OF AGRICULTURE, 1885-1950[1]

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Until the establishment of the Bureau of Plant Industry (now the Bureau of Plant Industry, Soils, and Agricultural Engineering) in 1901, the plant pathological research of the Department of Agriculture was conducted in the Division of Vegetable Physiology and Pathology. There, a small but able staff carried on research on diseases of vegetables, fruits, cotton, cereals, and other crops. One of the earliest accomplishments in vegetable pathology was the isolation (1894) of Fusarium oxysporum Schlecht f. niveum (E.F.Sm.) Snyder & Hansen, and the demonstration that this soil-borne vascular parasite was the cause of watermelon wilt. This work, which opened the way for later studies of the Fusarium wilts of cabbage, tomatoes, and other crops, was accompanied by a prediction that diseases of this type would be of constantly increasing importance.

Work on bacterial diseases of plants was new in the 'nineties and then, as for many later years, the Department's work was outstanding in this field. The organism, Erwinia trachephila (E.F.Sm.) Holland, causing bacterial wilt of cucurbits was isolated (1895) and it was shown to be transmitted by the striped and spotted cucumber beetles Acalymna vittata F. and Diabrotica undecimpunctata howardi Becker, respectively. The organisms causing bacterial wilt of tomatoes and other solanaceous crops, Pseudomonas solanacearum E.F.Sm., (1896) and bacterial blight of beans, Xanthomonas phaseoli (E.F.Sm.) Dowson, (1898) also were isolated and described. Studies of black rot of cabbage, Xanthomonas campestris (Pam.) Dowson, dealt in detail with the mode of infection and progress of the organism in the plant (1903).

Between 1904 and 1911, a wilt-resistant watermelon variety was produced by crossing a resistant but inedible citron with the cultivated melon. Selections of plants with desirable characters were made from a large F_2 population and through further selection a wilt-resistant, edible melon eventually resulted. This variety, Conqueror, never found favor in the markets but it enters into the parentage of several wilt-resistant melons of today. This work is of more than ordinary interest because it was one of the first attempts at synthesis of a variety resistant to a particular disease.

In 1907 the Office of Cotton, Truck, and Forage Crop Disease Investigations was established and its staff was gradually increased until the research included diseases of all the major vegetable crops. Also some work on bacterial diseases of vegetables was done in the Laboratory of Plant Pathology, a separate organization that specialized in bacteriological research. The work of that Office continued until 1928 when it became a part of the newly organized Division of Horticultural Crops and Diseases which, in 1932, took its present name, Division of Fruit and Vegetable Crops and Diseases. This Division was formed in the course of a reorganization in which the plant research was planned primarily around a crop or group of crops, with the combining of pathological and horticultural investigations of vegetables in a single section. This arrangement has led to an increasingly close correlation of the horticultural and pathological research that has given added breadth, balance, and effectiveness to work in both fields. From the start, much of the work on vegetable diseases has of necessity been carried on in sections of the country where the diseases under investigation are most damaging and prevalent. Many of the staff of vegetable pathologists have been and are stationed in the field and work in cooperation with State agricultural experiment stations. Much of the work reported here has been cooperative with one or more States.

In the period from 1900 to 1920, the field of plant diseases was still relatively unexplored and naturally, at first, there was need for more work on the isolation, identification, and description of plant pathogens than generally is the case today. However, the study of the parasite, its life history, and effects on the host are always necessary precursors of the development of control measures, and the need of practical means of control was not forgotten. The use of fungicides, seed disinfection, measures of sanitation, and modification of cultural practices all were beginning to play a large part in disease control. Disease resistance was recognized as the only apparent means for control of many diseases, but progress in this field still was comparatively slow although there was growing emphasis on this type of research.

The first World War brought a need for increased food production and a more general realization of the economic seriousness of vegetable diseases. During 1918-1919, the Office of Cotton,

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[1] The work on vegetable diseases as reported here does not include those of potatoes or those occurring in handling transportation, and storage of vegetable crops. The dates used refer to date of publication of the results described.

Truck, and Forage Crop Diseases maintained extension pathologists in many of the States, where they studied losses from disease and reported the occurrence of many diseases the importance of which had not been fully recognized and some of which were as yet unidentified. This period also marked the beginning of the Plant Disease Survey which helped to clarify and expand the pathologists' conception of the problems of disease incidence and control. As time went on, there was increasing pressure by growers, shippers, and processors of vegetables for more research on disease control, due in part to the increase of intensive production of these crops. As a result, the research on vegetable diseases was broadened and became organized into projects that included beans and peas, cabbage and related crops, celery, cucumbers and melons, lettuce, onions, tomatoes, and sweetpotatoes.

Since 1920 the investigations of vegetable diseases in the Department of Agriculture have undergone progressive changes in the relative emphasis on various types of research. After 1920 there was a rapid realization of the general prevalence of virus diseases on vegetable crops and the actual or potential losses from virus infection. Virus disease research increased in relative importance, and by 1930 was a major field of vegetable pathology.

From 1920 to 1935, the possibility of disease control by measures of sanitation was explored rather thoroughly and the value of eradication of perennial weed hosts of viruses and fungi, destruction of crop refuse, seed bed sanitation and disinfection, and crop rotation received considerable attention. It was found that such measures were of very definite value in control of certain diseases; but even for those there were often practical difficulties in the application by the average grower. As a result, there has been recently less general emphasis on research of this type, except for certain virus diseases.

Up to about 1925, research was fairly extensive on the control of diseases of celery, cucumbers, melons, and tomatoes by the available copper fungicides applied as sprays or dusts. For the next ten years, there was little work of this type, but after 1935 the need for disease control of leaf diseases on seedling tomato plants grown in the South for shipment to the North and the problems of control of powdery mildew, rust, and sclerotiniose of beans led to further research with fungicides, particularly the newer organic compounds.

The most marked trend in the work on vegetable diseases has been the increasing effort toward the development of varieties resistant to disease. This has been due partly to the realization that many virus diseases can be adequately controlled only through disease resistance. Many of the most damaging diseases of vegetables are caused by soil-borne fungi, and here again the only feasible means of control under our current cropping practices has been the production of resistant varieties. A number of leaf spot diseases can be checked by the use of fungicides, but even with the newer materials control is not entirely effective when climatic conditions are favorable to disease, and there is always the likelihood of lack of control because of faulty timing or inadequate methods of application by the grower.

In the Division of Fruit and Vegetable Crops and Diseases, the emphasis in the last 15 years has been toward research problems of regional rather than local importance and particularly those which are likely to require long-time research for their solution. At present, much of the vegetable disease research involves the search for and use of disease resistance.

In describing the investigations of vegetable diseases in the Department of Agriculture during the past fifty years it is impracticable to mention all of the research that has contributed to their progress. However, the account has been made sufficiently inclusive to give a fairly broad conception of the research in vegetable pathology. In order to view the work as a whole it has seemed best to discuss it on the basis of the major types of investigations involved rather than from the standpoint of research on individual crops. Therefore, the investigations have been grouped into three classes:

(1) Pathological research that includes descriptive mycology, studies of pathological history, variability of pathogens, modes of overwintering of fungi, bacteria, and viruses, effects of environment on infection and disease development, and the effects of nutrition on disease expression.

(2) Control by means other than disease resistance, including the use of fungicides, seed treatments, sanitation, and certain other methods of control.

(3) Development of varieties resistant to disease and research on the nature and inheritance of resistance.

PATHOLOGICAL INVESTIGATIONS

DESCRIPTIVE MYCOLOGY -- The identification and description of fungi and bacteria causing plant diseases has been part of the work done by pathologists throughout the country in laying the foundation for future work on disease control. The task has required careful field observations, accurate mycological study, a knowledge of the host plants and their anatomy, and the development of new techniques of isolation, culture, and inoculation that today are the common tools of the pathologist. In the course of about 55 years, pathologists in the Department of Agriculture have been the first to describe many of the fungi and bacteria causing disease in vegetables. Among these diseases are the following, listed by crops:

Bean: Bacterial blight (*Xanthomonas phaseoli*), bacterial wilt (*Corynebacterium flaccumfaciens* (Hedges) Dowson), anthracnose of lima bean (*Colletotrichum truncatum* Andrus & Moore).
Cabbage and related crops: Cauliflower leaf spot (*Pseudomonas maculicola* (McCul.) F. L. Stevens).
Cucurbit crops: Bacterial wilt (*Erwinia tracheiphila* (E. F. Sm.) Holland), bacterial leaf spot of cucumber (*Pseudomonas lachrymans* (E. F. Sm. & Bryan) Dowson), leaf spot of squash (*Xanthomonas cucurbitae* (Bryan) Dowson), cucumber leaf spot (*Stemphylium cucurbitacearum* Osner), cottony leak of cucumbers (*Pythium aphanidermatum* Drechsler), watermelon wilt (*Fusarium oxysporum* f. *niveum*, blossom end rot of watermelon (*Pythium acanthicum* Drechsler).
Eggplant: Fruit rot (*Phomopsis vexans* (Sacc. & Syd.) Harter).
Lettuce: Bacterial wilt (*Xanthomonas vitians* (N. A. Brown) Starr & Weiss), bacterial wilt (*Pseudomonas viridilivida* (N. A. Brown) Holland).
Onion: Neck rot (*Botrytis byssoidea* Walker and *M. squamosa* Walker).
Pea: Root rot (*Aphanomyces euteiches* Drechsler).
Rhubarb: Foot-rot (*Phytophthora parasitica* var. *rhei* Godfrey).
Sweetpotato: Foot-rot (*Plenodomus destruens* Harter), dry rot (*Diaporthe batatatis* Harter and Field), mottle necrosis (*Pythium* spp.).
Tomato: Bacterial wilt (*Pseudomonas solanacearum*), bacterial canker (*Corynebacterium michiganense* (E. F. Sm.) H. L. Jensen), bacterial speck (*Pseudomonas punctilans* (Bryan Dows.), fruit rot (*Isaria clonostachoides* Pritchard & Porte).

Other mycological and descriptive work has included studies of a number of species of *Pythium*, *Phytophthora*, and *Aphanomyces* causing roots rots of peas, beans, lettuce, celery, spinach, and other crops. There also have been extensive investigations of fungi parasitic on nematodes and of predaceous fungi that capture nematodes, spring tails, amoebae, rotifers, and other animalcules found in the soil.

In the above list, 23 of the 25 diseases mentioned were described prior to 1926, while 17 of the 18 known virus diseases described by Department pathologists (see section on plant viruses) were reported after that date. While the difference would be expected in view of the fact that the field of fungus and bacterial parasites had been quite thoroughly explored by 1925 when the work on viruses had really just begun, it still is a reminder of one of the changes that have occurred in the predominant types of pathological investigations.

In addition to diseases caused by fungi, bacteria, and viruses, descriptions also have been made of diseases due to other causes or of unknown cause, which include:

Non-parasitic diseases: Celery blackheart due to excess soil moisture, and bald head of beans caused by threshing injury.
Diseases of unknown cause: Brown blight of lettuce, ghost spot of tomatoes (possibly due to insect puncture), and phyllody of beans (possibly related to tomato big bud).

PATHOLOGICAL HISTOLOGY -- Research in the pathological histology of invasion of the host by plant pathogens often has been a necessary part of the investigations of diseases caused by fungi and bacteria.

In club root of cabbage, *Plasmoidophora brassicae* Wor., it was shown (1918) (1934) that the young plasmodia migrate by direct penetration of the cells and also by dividing with the host cell in its division. The most rapid advance of the parasite was found in the cambium of the root and hypocotyl. A migration up and down the cambium from the infection point accounts for the spindle formation of the clubbed roots. In stems the host response is chiefly in the cortex and galls of spheroid shape are formed.

Studies were made of the pathological histology of bacterial blight of bean (1930) in which it was found that the organism invades stomata and wounds, penetrates intercellularly, and eventually enters the xylem tubes where it can break through thin portions of the xylem and invade the parenchyma. The seeds are invaded from the pod cavity through the micropyle or by way of xylem strands through the funiculus.

Comparative studies also were made of invasion of beans by the organisms causing bacterial wilt, bacterial blight, and halo blight, (Pseudomonas phaseolicola (Burkh.) Dowson) (1931). It was shown that the wilt organism is chiefly a vascular parasite and does not infect through the stomata, as do the others which fill the stomatal cavities and produce spots with a watersoaked appearance.

In investigation of bacterial canker of tomatoes (1928) it was demonstrated that the organism could enter the vascular bundles of the fruit and penetrate the fleshy outer coat of the seed, where it remained viable and caused cotyledonary infection. In the case of fruit infection of tomatoes by the nailhead rust fungus, Alternaria tomato (Cke.) Weber, it was found (1920) that the resistance of the fruit to invasion becomes greater with age and is correlated with the increased resistance of the cuticle to puncture.

When sweetpotatoes are infected by the black rot fungus, Endoconidiophora fimbriata (Ell. & Halst.) Davidson, it was found (1921) that after the hyphae had penetrated a short distance below the surface of the tuber a layer of cork cambium four to six cells deep was formed beneath the invaded tissue. It was felt, though not proven, that this cork formation may account in part for the lack of any deep penetration of the tissues by this fungus.

VARIABILITY OF PATHOGENS -- Studies of possible variations in pathogenicity of parasitic fungi have been of particular importance in relation to the development of disease resistant plants. In the case of cabbage yellows (Fusarium oxysporum Schlecht. f. conglutinans (Wr.) Snyder & Hansen), it was found (1934) that numerous collections of the fungus from widely separated localities were quite uniform in pathogenicity.

Similar work (1940) with the fungus causing wilt of tomatoes (Fusarium oxysporum Schlecht. f. lycopersici (Sacc.) Snyder & Hansen), showed a definite range of pathogenicity and cultural characteristics in the many isolates tested, and considerable saltation within individual monoconidial isolates. However, while certain strains showed especially high virulence, there was no marked difference in host selectivity with respect to resistant and susceptible varieties. A study (1942) also was made of the pH relation of varying strains of the fungus in culture and of the comparative toxic effects on the plant of extracts from mild and virulent forms of the fungus (1943).

Investigation of bean rust (Uromyces phaseoli var. typica Arth.), in 1935, demonstrated the existence of 2 physiologic races of the fungus, and by 1948 24 races from the United States and Hawaii had been identified by the use of 7 differential hosts. The degree of susceptibility to 14 of these races was determined for a large number of bean varieties.

In the case of powdery mildew of cantaloup, (Erysiphe cichoracearum DC.), it was found (1938) that two races of the fungus were present in the cantaloup-growing sections of the West. The second race, which may represent a mutation or an introduction, has proved of great importance from the standpoint of disease resistance, as will be shown elsewhere.

MODES OF OVERWINTERING OF FUNGI, BACTERIA, AND VIRUSES -- There have been extensive investigations of the life histories of various fungi and bacteria and of the means of overwintering of viruses, because of the evident importance of overwintering in relation to the spread and control of disease.

Transmission of plant pathogens on or in the seed has been demonstrated in the case of such diseases as bacterial blight of bean (1897), bacterial wilt of bean (1926), cucumber angular leaf spot and anthracnose (Colletotrichum lagenarium (Pass.) Ell. & Halst.) (1918), black-rot and black-leg (Phoma lingam (Fr.) Desm.) of cabbage and related crops (1922-24), Phomopsis fruit rot of eggplant (1914), and bacterial canker of tomato (1928). In the last case the organism was found to live for some years in seed (1942). In sweetpotatoes it was found (1913-16) that infection commonly occurs in plants produced from "seed stock" infected with stem rot, (Fusarium oxysporum Schlecht. f. batatas (Wr.) Snyder & Hansen), foot-rot, scurf (Monilochaetes infuscans Halst.), black-rot, and certain other diseases.

It was demonstrated (1920) that the virus of cucumber mosaic may possibly be seed-transmitted, but this is so rare as to be of no importance in control. However, about 10 percent of seeds from the mosaic plants of common wild cucumber (Micrampelis lobata) produced mosaic plants. It has been shown that seed freshly extracted from tomato fruits infected with common tobacco mosaic (Marmor tabaci Holmes) and the leaf-withering strain of this virus (var. siccans) will produce 1 to 3 percent of mosaic seedlings; but when the same seed is aged for 30 days or more, no seed transmission occurs although the virus can be readily recovered from the seed coat (1939, 1942).

The overwintering of plant pathogens in the soil has been a phase of the research on many vegetable diseases and only those will be mentioned where overwintering in the soil was demonstrated for the first time or the findings are of some special significance. Such investigations include cabbage black-leg and black-rot (1922), angular leaf spot and anthracnose of cucumber (1918), bacterial canker of tomato (1942), Phomopsis of eggplant (1914), brown blight of lettuce (1931), big vein (virus) of lettuce (1934), onion smudge (1921), onion neck rot (1925), sweetpotato foot-root (1913), sweetpotato scurf (1916), sweetpotato mottle necrosis (1923). All of the pathogens causing these diseases were found to persist for at least one year on crop debris in the soil and many of them for much longer periods. Big vein is of especial interest since it is one of the few plant viruses that persist for any extended period in the soil. In addition to the above it has been shown that the viruses of ordinary tomato mosaic (M. tabaci) and single-virus streak (M. tabaci var. canadense Holmes) (1930) may remain active for three months in greenhouse soils though they were not found to overwinter to any appreciable extent in the field. It has also been shown (1942) that the organism causing bacterial wilt of tomatoes overwinters as far north as New Jersey.

The overwintering of viruses on perennial weed hosts was demonstrated in 1925 in research on ordinary cucumber mosaic (Marmor cucumeris). This virus was found on milkweed (Asclepias syriaca L.), pokeweed (Phytolacca decandra L.), and wild ground-cherries (Physalis spp.), and it was demonstrated that it could be carried to the cultivated hosts by aphid vectors. The infected weed hosts were found exclusively near fields that at some time had grown cucurbit crops or in the vicinity of home gardens. This last fact served to explain the greater occurrence of the disease in cucumber fields near towns and villages than in those at a distance in the country. Later work with the southern celery strain (var. commelinae) of cucumber mosaic virus in Florida showed that it was extremely prevalent on a monocotyledonous host, Commelina nudiflora, which occurred along ditch banks and in other moist places throughout the celery-growing area. In these investigations it was also shown that a number of other perennials, both wild and cultivated, were subject to infection by the virus.

It has also been found that the cabbage mosaic complex (see section on virus diseases) overwinters on certain cruciferous hosts, such as shepherd's purse (Capsella bursa-pastoris) and penny cress (Thlaspi arvense), and on cabbage seed plants.

An unusual case of the overwintering of a bacterial pathogen in insects was discovered in the course of investigations of bacterial wilt of cucumber (1920), which showed that the causal bacteria are to be found in the intestinal tract of the two species of cucumber beetles that disseminate the disease. Evidence indicated that the bacteria also overwinter in the bodies of hibernating adult beetles. Since the organism is not carried in the seed or soil the insects seemingly are the only means of its overwintering. In 1921 beetles emerging from hibernation abnormally early in the spring in Wisconsin produced wilt infection on caged plants in the greenhouse, a fact that seemingly confirms the likelihood of this means of overwintering.

VIRUS DISEASE INVESTIGATIONS- - The work on virus diseases in the Department of Agriculture has included viruses affecting bean, cabbage and cauliflower, celery, cucumbers and melons, lettuce, tomatoes, and sweetpotatoes. This work has involved identification of new viruses and studies of others already described. In addition to certain work on overwintering of viruses and the effect of environment on disease expression, the investigations have also dealt with many other phases of virus reasearch.

Legume Viruses: Research on viruses of beans and peas has resulted in the identification of a number of new viruses, chiefly those of beans. Lima bean mosaic, described in 1938, was found to be caused by a strain of cucumber mosaic (Marmor cucumeris var. phaseoli Holmes). Southern bean mosaic (bean virus 4, M. laesiofaciens Zaumeyer & Harter), described in 1943, was found to have a thermal inactivation point of 90° C, which is much above that of most viruses. On certain varieties this virus produces systemic symptoms and on others only a necrotic spotting of the inoculated leaves. A disease known as greasy pod of beans was found (1947) to be caused by a virus that may be a strain of common bean mosaic (M. phaseoli Holmes). This virus produces the symptoms known as "black-root" in varieties where resistance to common mosaic stems from Corbett Refugee, Kentucky Wonder, and Creaseback types. These symptoms were not produced in resistant varieties derived from strains of U. I. Great Northern No. 1 or Robust. Pod mottle of beans (M. valvolarum Zaumeyer & Thomas), which causes systemic symptoms somewhat similar to but more intense than those of southern mosaic, was reported in 1948. Local lesions of this virus differ from those of any other virus reported on beans. All varieties tested were susceptible either to systemic or to local infection. Red node of beans was found (1949) to be caused by a strain of tobacco streak virus (M. orae Holmes), and a virus known as yellow stipple was discovered, which causes a mild mottle on snap beans but in most field varieties produces small, yellow necrotic spots. Studies also were made (1935) of the relation of other legume mosaics to bean.

In 1925 a mosaic of garden pea transmissible to sweetpea and red clover (Marmor leguminosarum Holmes) was described. Later (1938) pea streak caused by M. trifolii Holmes was reported. Three other mosaic diseases of pea were described (1940) as caused by pea mosaic virus 4, by pea mosaic virus 5 (M. fastidiens Holmes), and by alfalfa mosaic virus 2. It was also shown (1936) that mosaic viruses of white clover, red clover, white sweetclover, and alsike clover were transmissible to pea.

Crucifer Viruses: In 1921 a mosaic (Marmor brassicae Holmes) was described on Chinese cabbage, mustard, and turnip, but no further work was done on this disease at the time.

Cabbage mosaic, which has caused serious damage to this crop in the Middle West and in the seed-growing sections of the Pacific Northwest, was shown (1945) to be caused by a combined infection of the plants with a strain of the cabbage black ring virus (Marmor cruciferarum Holmes) of California and a strain of the cauliflower mosaic virus of California (M. brassicae Holmes). It also was shown that ring necrosis of cabbage is caused by the black ring virus. Host range and field studies have shown that the mosaic viruses, which are transmitted by aphids, overwinter chiefly on cabbage seed plants or on cruciferous weeds such as shepherds-purse (Capsella bursa-pastoris (L.) Medic.) and pennycress (Thlaspi arvense L.).

Cucumber Mosaic Virus: Cucumber mosaic caused by Marmor cucumeris Holmes was studied extensively (1918-1925), with particular reference to virus host range and overwintering. This virus was one of the first whose hosts were found to extend over a wide range of plant genera. It was also found transmissible to many cucurbit hosts, including squash, pumpkin, and muskmelon, but not watermelon. These studies resulted in one of the earliest demonstrations of the fact that perennial weeds may act as reservoirs of the virus for primary infections of cultivated crops. (See section on overwintering of plant pathogens, above). Later work (1928) showed that an aphid vector (Aphis gossypii Glover) can transmit the virus after a brief feeding on a mosaic plant but did not continue to carry it after the first feeding period. It was later found (1930) that a serious disease of celery in Florida known as brown-stem was due to a virus whose common wild host was a perennial monocotyledonous weed, Commelina nudiflora L.. This was the first example of the transmission of a virus from a monocotyledonous to a dicotyledonous host. Later studies (1934-35) indicated that this southern celery mosaic virus was similar to but not identical with ordinary cucumber mosaic, and later work by others supported the belief that it was a strain of this virus, M. cucumeris var. commelinae Holmes). Studies of the host range (1936) showed that 93 species in 23 genera apparently were susceptible to infection by artificial inoculation or by aphids. Forty-six of these species were found naturally infected.

Virus Diseases of Lettuce: Lettuce mosaic (Marmor lactucae Holmes) was described in 1921 and shown to be transmissible by aphids.

Big vein of lettuce was reported in 1923 and it was demonstrated that it could overwinter for some years in the soil, but no cause was found for the disease although it was shown that it could be destroyed by steam sterilization of the soil. In 1944 limited experiments in cooperation with the Bureau of Entomology and Plant Quarantine indicated the possibility of transmission by a root aphid (Pemphigus lactucae Fitch.) but no definite conclusions could be drawn. In 1945 it was found that the disease is transmissible by inoculations of roots or leaves with juices of the roots of diseased plants but no infection was obtained by inoculations with leaf juices. Other experiments (1945) indicated a possibility that fresh leaf tissue from diseased plants might cause infection if placed in contact with the roots. No evidence of seed transmission was obtained but it was found that the virus could persist for 8 years in the soil.

Tomato Virus Diseases: Investigations of virus diseases of tomatoes have included (1928) studies of the effect of air and soil temperature on the development of double virus streak caused by a combined infection with ordinary tobacco mosaic (Marmor tabaci) and the X-virus of potato (Annulus dubius Holmes var. vulgaris Holmes). Tomato mosaic was found to live for 90 days in greenhouse soils (1928), as also the strain causing single-virus streak, but no evidence of overwintering in the field was secured. Seed tramsmission (see section on overwintering) was demonstrated (1937) in the case of seed freshly extracted from mosaic-infected fruits. A disease caused by combined infection of greenhouse plants with the viruses of cucumber and tobacco mosaic was described (1939). In 1942 a report was made of a leaf-withering strain of tobacco mosaic (M. tabaci var. siccans Doolittle & Beecher), which causes severe defoliation of tomatoes. Studies with the virus of tomato curly top (Ruga verrucosans Carsner & Bennett) in Utah and Oregon dealt chiefly with the effect of light, temperature, nutrition, and other factors on symptom expression and are discussed in the section dealing with environment in relation to disease. Big bud (Chlorogenus australiensis Holmes) of tomatoes was reported from Oregon (1942) and shown to be transmissible by grafting.

Virus and Virus-like Diseases of Sweetpotato: A so-called mosaic of sweetpotatoes was studied (1928), but no evidence was found that it was transmissible by mechanical inoculation or grafting, and it was felt that it was not caused by a virus. A virus disease known as feathery mottle was found (1946) to be transmissible only by grafting, although it produces symptoms similar to those of the mosaic group of viruses. It apparently is rare and has been described as Flavimacula ipomeae Doolittle & Harter.

EFFECTS OF ENVIRONMENT ON DISEASE EXPRESSION AND DEVELOPMENT -- The relation of environment to disease has been extensively investigated in the course of research on fungous, bacterial, and physiologic diseases and to some extent with certain plant viruses. The work has dealt with the effects of air and soil temperature, soil moisture, soil acidity, nutrient chemicals, and light, in relation to the growth of fungous and bacterial pathogens in culture and to the occurrence of infection and the development of disease in the host. The examples of such work discussed here are only illustrative and do not include a number of other similar investigations by workers in the Department of Agriculture.

Temperature: In cabbage yellows the fungus is most destructive at temperatures of about 26° C., and soil temperature is the most common limiting factor in disease development. It was found (1930) that cabbage seedlings having an homozygous resistance (Type A) governed by a single dominant gene were not affected at temperatures of 26° C., whereas plants carrying a genetically more complex and incomplete resistance (Type B) are badly injured at the same temperature (1934, 1937). This fact has proved a most valuable criterion for selecting seedlings when breeding for resistance.

At constant soil temperatures the infection of tomato plants with the organism causing bacterial wilt was sharply checked at 60° F., while at temperatures of 70° or above there was a progressive increase in the rapidity and severity of disease development. With bacterial canker of tomato soil and air temperatures of 27° to 28° C. were found most conducive to severe development of the disease.

The fungus causing downy mildew of lettuce (Bremia lactucae Reg.) produces conidia which may germinate indirectly by production of zoospores or directly by germ tubes. It was discovered (1923) that conidia formed during cool weather produce zoospores most readily, especially in the dark at about 10° C., but during warm weather germination is largely direct.

Soil Moisture: Study of effects of varying soil moisture have been especially important with blackheart of celery, which causes a rapid and destructive yellowing, blackening, and collapse of the young leaves. Investigation showed (1924) that it was caused by improper water relations in the soil and would develop if the soil moisture suddenly approached the saturation point after periods of low moisture. High temperatures favor the disease.

Controlled experiments with blossom-end rot of tomatoes showed that plants grown continuously with a moderate supply of soil moisture were not subject to the disease but, when the water content of the soil was rapidly decreased after being very high, the disease regularly occurred. Excessive fertilization with nitrogen also increased the likelihood of incidence of blossom-end rot.

With club-root of cabbage a decrease in soil moisture was found (1930) to be accompanied by reduced infection, and in soils held constantly at a very low moisture level no infection occurred. However, a period of 18 hours at favorable moisture was found to be enough for infection. The progress of the club-root disease is checked in alkaline soils and it was shown that in well-watered soils with a pH of 7.2 or above there was little infection. In drier soils (1934) this did not hold, apparently because of a lack of sufficient movement of alkaline particles to neutralize the CO_2 constantly given off immediately about the rootlets where infection occurs.

Rainfall: Rainfall has been shown to be responsible for much of the dissemination of diseases such as angular leaf spot and anthracnose of cucumber (1920). Such dissemination has been of particular significance with black leg and black rot of cabbage (1922, 1934), where dissemination during the growing season is largely by rain. Both of these diseases are prevalent in the Eastern, Central, and Southern States but are almost unknown in Pacific Coast sections where most of the cabbage seed is grown. Study of the climatic conditions affecting disease development have shown (1934) that lack of rain during the summer discourages the development of black leg and black rot on seed crops in this section.

Light Intensity: With curly top of tomatoes and beans, (1924-1942) various studies of the effect of environment on the development of the disease showed that symptom expression is directly affected by light intensity, which, when reduced, will practically suppress symptoms of the disease. No definite effects of temperature, humidity, or rate of evaporation from the leaves could be found. Nutrition did not affect the incidence or development of the disease and biochemical studies did not show striking differences in diseased and healthy plants.

Nutrition: The effects of nutrition on the development of disease has been a subject of various field and laboratory investigations. With blackheart of celery, field experiments (1925) showed that the incidence and severity of the disease were not related to nutrition and that the amount or source of nitrogenous fertilizers used did not, as had been believed, influence the development of the disease.

Studies on the fungus causing cabbage yellows (1945) were conducted in sand cultures with susceptible, tolerant, and resistant plants. Disease was retarded by an increase in salt concentration except at very low levels. Low nitrogen and low phosphorus tended to retard and low potash to increase the progress of the disease, but suppression or increase in disease severity was not correlated with growth. The experiments were conducted at varying soil and air temperatures, and it was found that the effects of nutrients were conditioned by temperature and by the degree of host resistance.

It has been found (1941) that cabbage, cauliflower, turnip, and rutabaga are susceptible to injury by boron deficiency in the soil. In cabbage, the symptoms consist chiefly of the development of watersoaked spots in the fleshy pith of the core and stem, which may become brown; and hollow cavities develop at times. Cauliflower curds are discolored and the core is split. In turnips there is a discoloration of the roots, which develop a hollow center.

Phytotoxicity of Insecticide Residues: The question of possible phytotoxicity of residues of DDT and other new organic insecticides, with particular reference to the effects of their accumulation in the soil, is now under investigation. It has been shown that such effects may occur, and work is in progress with a number of vegetable and other crops.

Cultural Practices: It has been found that cultural practices may have a bearing on disease development. Tomato seedlings grown in the South for shipment to the North are pulled in the field and tied in bundles, which are usually left exposed to the sun for some time before removal to the packing house. Studies of stem infection by the fungus causing early blight (Alternaria solani (Ell. & Martin) Sor.) proved that susceptibility to stem infection increased with the degree of wilting of the plant. Slight mechanical injuries to the stem also increased the amount of infection (1942). Plants allowed to remain in the field too long before pulling showed significantly greater amounts of stem canker.

CONTROL OF VEGETABLE DISEASES BY METHODS OTHER THAN THE USE OF RESISTANT VARIETIES

USE OF FUNGICIDES FOR DISEASE CONTROL -- Early experiments in the use of fungicides for control of vegetable diseases (1904-08) were with bordeaux mixture for control of downy mildew (Pseudoperonospora cubensis (Berk. & Curt.) Rostow.) and anthracnose of cucumbers in the South. It was shown that spraying gave good increases in yield, and detailed directions were supplied for the preparation of the fungicide. In 1920 extensive experiments on the control of anthracnose of watermelon showed that the use of bordeaux mixture when, applied so as to give proper coverage of the vines, would greatly reduce losses from this disease.

Experiments on control of early blight (Cercospora apii Fres.) and Septoria spot (Septoria apii (Berk. & Curt.) Chester) of celery were conducted in Florida (1919-1924). A comparison was made between various formulations of bordeaux mixture and copper-lime dust in which bordeaux mixture gave definitely better control.

In experiments on control of Septoria leaf spot of tomatoes (S. lycopersici Speg.) (1919-1924), it was found that five applications were necessary to give effective reduction of losses from the disease and that at least 100 gallons of spray must be applied per acre. Trials were made with various strengths of bordeaux mixture and it was noted that a 4-2-50 formula gave good results, thus anticipating the later use of the low-lime mixture which is now commonly recommended. Additions of rosin-fish oil soap was thought to increase the effectiveness of the fungicide. It was pointed out that spraying was profitable only when the crop was grown on fertile soils and disease was severe.

In 1936 investigations were started on the control of diseases of tomato seedlings grown in the South for shipment to the North. The chief problem at that time was the control of Alternaria stem canker and leaf spot, but since 1946 there also has been the problem of late blight (Phytophthora infestans (Mont.) DBy.) control. Spraying and dusting experiments have continued to the present and have included tests in which the development of disease on plants treated in the seedling beds is observed after they have been transplanted in the North. Bordeaux mixture was found to be injurious to seedling plants and it was shown (1942) that when applied just prior to shipment many plants did not survive after transplanting in the field. Later work has shown that fixed copper fungicides can be used with safety and will give fairly adequate control of disease. Many of the newer fungicides have been and are still being tested, particularly the carbamate compounds which show definite promise for use on seedlings.

In experiments on the control of tomato anthracnose (Colletotrichum phomoides (Sacc.) Chester) spraying with ziram and ferbam gave control superior to copper fungicides and appeared equally effective against early blight (1947).

Experiments with fungicides for control of rust of beans showed (1946) that sulfur is extremely effective in rust control. Investigations on field beans in the West have proved that two applications per season may increase the yield of seed as much as 1,000 pounds per acre, and a single application gave increases as high as 600 pounds per acre. Work on powdery mildew of beans (Erysiphe polygoni DC.) in the South (1936) also demonstrated the value of sulfur dust in the control of this disease. Studies on the control of Sclerotinia infection of beans in Oregon indicate (1950) that aerial infection can be much reduced by spraying with ziram plus a wettable sulfur. Promising results also were obtained with ziram and sulfur used singly, bismuth subsalicylate, ferbam plus sulfur, copper-zinc, and copper-zinc chromate. Dusting with ziram and wettable sulfur also reduced aerial infection. No control of basal infections was obtained by use of fungicides. The degree of control obtained to date is still short of what is required for most satisfactory commercial production.

SEED TREATMENT -- Several types of seed treatment for control of vegetable diseases have proved of definite value. In 1920 it was shown that losses from angular leaf spot of cucumber and anthracnose of cucumber and melons could be reduced by treatment of the seed with a 1-1000 solution of bichloride of mercury. Field tests showed the effectiveness of the treatment, which was soon widely used on seed of pickling cucumbers and continues to be used today.

Treatments of cabbage seed as an aid in control of black leg and black rot were tested (1924), and it was found that, while a 1-1000 solution of bichloride of mercury would effectively kill the black rot bacteria it would greatly reduce but not entirely destroy the black leg fungus. This was recognized as a serious limitation in the treatment and it was shown that a hot water treatment for 30 minutes at 122° F. would free the seed of both organisms, although there was danger of injury to germination. This latter method has since become the one recommended, because of increasing evidence of the limitations of bichloride of mercury for black leg control.

Investigations of seed transmission of tomato bacterial canker showed that treatments with bichloride of mercury and other chemicals did not effectively free the seed of the canker bacteria, particularly when used on freshly extracted seed. However, it was found (1933) that fermentation of freshly extracted seed and crushed fruit pulp for 96 hours at temperatures close to 70° F. gave very effective control of seed-borne infection. Later it was found that seed extracted mechanically without fermentation could be effectively disinfected by soaking for 24 hours in an 0.8% solution of acetic acid. Both treatments proved definitely superior to previous chemical treatments.

SANITATION -- Sanitation as a factor in disease control has presented important possibilities in the case of certian virus diseases. Many investigations also have shown the danger of contamination of seed bed and field soils with certain parasitic fungi and bacteria and recommendations have been made for methods of avoiding such contamination.

With cucumber mosaic the discovery of the overwintering of the virus in perennial weed hosts led to extensive field experiments on the control of the disease by eradication of wild hosts (1926). Experiments with an isolated field with a known history of severe mosaic damage on successive cucumber crops resulted in the occurrence of only slight losses when milkweed was destroyed in its immediate vicinity. Further work with a group of commercial plantings where the disease had been severe demonstrated the practical possibility of control by the grower. It was found that such perennial weeds as milkweed and Physalis spp. need to be kept down only in the immediate vicinity of the fields to secure adequate control.

In Florida it was found that the southern celery mosaic virus occurred on the creeping day flower (Commelina nudiflora) along ditch banks, roadsides, and frequently near seedbeds, and a study of the progress of mosaic in the field showed that the first infection commonly occurred adjacent to the spots where this weed was growing. Experiments in which the weeds about certain fields were destroyed by cultivation or chemical treatment demonstrated that the incidence of mosaic could be greatly reduced by such methods.

In work on the control of cabbage mosaic in seed-crop cabbage fields in the Pacific Northwest (1946), it was shown that losses from mosaic, which had previously been severe, could be greatly reduced by locating the seedbeds on farms outside the district in which the seed crop is grown. The adoption of this method has resulted in a sharp decline in the occurrence of mosaic on the seed crop.

OTHER METHODS OF CONTROL -- Other methods being tested for disease control include the application of cyanamid to the soil in advance of planting as a means of reducing the severity of Sclerotinia on beans in Florida. On marl soils this method shows promise but on sandy soils it has not been effective. In the same investigations (1949) it was found that, where feasible, the flooding of the fields for four or five weeks during the summer was a means of killing the sclerotia, which soften and rot under such conditions.

The fact that shade reduces the incidence and expression of curly top in tomato and beans has been used in a method of control that, while not adapted to commercial use, has value for the home gardener. The effect of shade is due largely to the fact that the leafhopper vector does not frequent shaded locations, but there also is an arresting effect on the development of the disease in infected plants. Shading with slatted or muslin-covered frames has been found to reduce the losses considerably, and some protection also has been found (1938) when small plants are protected by tent-like strips of muslin when small. After the plants touch the cloth it is removed and at this stage of growth the likelihood of injury is much reduced. In commercial field plantings of tomatoes it also has been found (1942) that close planting (10 inches) within rows of normal width considerably reduces losses from the disease and increases yields.

DEVELOPMENT OF VARIETIES RESISTANT TO DISEASE

BEANS -- Research on the development of beans resistant to disease was initiated in 1921. Between then and 1925 a large collection of varieties and hybrids was assembled and tested for resistance to various diseases. Gradually the work became concentrated largely on development of resistance to rust, virus diseases, and halo blight. In 1940 varieties of Kentucky Wonder, No. 3 and No. 4, which were resistant to a number of races of rust, were introduced. Studies of inheritance to six races of rust showed (1941) that resistance to races 1 and 2 was due to a single dominant factor, but more than one factor was involved with the others. Resistance was dominant in the case of four races and incompletely so in two. In 1946 two varieties of field beans with high resistance to many races of rust, Pinto No. 5 and Pinto No. 14, were introduced. These are proving valuable in the West, where rust is a serious problem in field beans.

Resistance to mosaic in beans was studied in the trials of 1921-25, but only the variety Robust showed resistance. In later work (1935) the variety U. S. No. 5 Refugee, which is resistant to common mosaic, was introduced. In 1942, Logan, a variety resistant to powdery mildew and to common mosaic, was released. This variety is especially suited to the South. In 1948 a mosaic-tolerant bean, Rival, and also Contender, a variety resistant to powdery mildew and mosaic, were introduced and in 1949 a mosaic-resistant variety, Topcrop, was released. Work on resistance to halo blight and on multiple virus resistance is in progress, and efforts are being made to develop lima bean varieties resistant to downy mildew (Phytophthora phaseoli Thaxt.) and to nematodes.

Curly top is very destructive to beans in many parts of the West, particularly in Eastern Oregon and Washington. Work on the development of snap beans resistant to the disease has been in progress for some years, but the only resistant parental material so far discovered has been limited to field bean varieties such as Red Mexican, California Pink, and Burtner, the last-named a variety whose young pods can be used as snap beans. The work of combining adequate horticultural type with resistance has been difficult in hybrids of these varieties with snap beans. In 1943, Pioneer, the first curly-top-resistant snap, was introduced. It is not suited to commercial use but provides home gardeners with a snap bean that can be grown successfully where all susceptible varieties fail because of curly top injury. Recent work gives promise of ultimate production of resistant snap beans of desirable quality for general commercial use. In this work mosaic resistance is being combined with resistance to curly top.

CABBAGE -- The work on development of cabbage varieties resistant to disease began with research on cabbage yellows in 1918. The fungus causing yellows (Fusarium oxysporum f. congutinans) was a serious menace to the crop in many sections of the Central, Eastern, and Southern States and although two yellows-resistant varieties had been produced by the Wisconsin Agricultural Experiment Station, it was evident that a number of resistant kinds were needed to suit varying climatic conditions and seasonal and market requirements.

It was known that the earlier resistant varieties varied in their behavior with respect to disease. Later it was found that their susceptibility increased with high soil temperatures. Investigations on the effect of temperature on the disease had shown that plants homozygous for resistance remained healthy at constant temperatures of 26° C., while the older varieties either showed no resistance or only a certain percentage of the plants survived. It was thus evident that a more complicated resistance, known as Type B, existed in such varieties, in contrast to the Type A resistance of the homozygous-resistant lines. This latter type, which is governed by a single gene dominant over susceptibility, was the first such single-factor difference to be reported for diseases caused by vascular Fusaria.

In the later breeding work the difference in reaction to soil temperature proved to be a very useful means of selecting individuals carrying the A type resistance in breeding progenies. This type was found to be present in most of the older varieties of cabbage used in this country, although only a small percentage of the plants carry it. Continued work on resistance has resulted in the introduction of a series of resistant varieties ranging from early to late season types and carrying close to 100 percent Type A resistance. At present the list includes varieties which supply resistant counterparts of all of the commercial varieties in common use and in many cases these are superior to the older types in horticultural quality.

Histological studies (1930) have shown no morphological difference in the roots of resistant and susceptible cabbage plants that would account for resistance. Later work (1935) on penetration by the fungus of the roots of resistant and susceptible plants showed that with Type A resistant seedlings the fungus may invade the cortex slightly but does not become established in the vascular system. In plants with Type B resistance there is some vascular invasion but it is restricted to a few localized vessels. In susceptible plants the fungus readily traverses the cortex and enters the vascular system. Resistance appears to involve degree of invasion and no morphological differences are apparent.

Work on resistance to club root of cabbage has been in progress for some time and has proven a more difficult problem than that of yellows resistance. Trials have shown no varieties of cabbage, cauliflower, brussel sprouts, kohlrabi, or collards possessing any resistance to the disease. Garden kale also is susceptible but certain stock kales have high resistance. Tests of club root resistance in turnips (1939) showed that some varieties are resistant and other susceptible. These results are in accord with those of workers in Europe. Most varieties of rutabagas tested showed no infection on infested soils. This fact indicates that there may be a difference in the pathologic behavior of certain strains of the club root organism, since in Europe some of the varieties tested have been found very susceptible. A study of the pathogenicity of the organism as collected from widely distant localities in this country indicated little difference in pathogenicity.

Attempts at securing crosses of cabbage with resistant varieties of turnips have failed, and similar crosses between resistant kales and cabbage have proven difficult. However, a cabbage-kale cross was found in the field and has been used in breeding work that is now in progress. Studies on the nature of resistance (1939-1945) to club-root has thrown much doubt on the European theory that resistance in black mustard is related to the presence of allyl isothiocyanate. Some collections of mustard have proved very susceptible and work with its volatile oil and with a related compound have shown no correlation between oil content and resistance in the plants tested.

CUCUMBER -- Work relating to disease resistance in cucumber has been confined to mosaic and bacterial wilt. Extensive tests of native and foreign varieties (1933-35) showed that in the varieties tested, aside from Chinese Long whose mosaic resistance was already recognized, only two varieties, Tokyo Long Green and Tokyo Dark Green, possessed marked resistance to mosaic. These varieties appeared to be practically identical in horticultural characters. Strains of Chinese Long and Tokyo Long Green were developed that possessed high mosaic resistance, and in field tests it was found that the latter variety showed definite tolerance of bacterial wilt infection. Hybrids of Tokyo Long Green and a variety known as Vickery's Forcing showed increased resistance compared to that of Tokyo Long Green, and certain hybrid selections were obtained that showed marked tolerance (1938) but whose horticultural characteristics were not fully desirable. In 1942 this work was held in abeyance because of need for work on more important food crops during the war and has not yet been resumed. Seed stocks are being maintained and testing for disease resistance has been continued with foreign cucurbit introductions.

MUSKMELON AND WATERMELON -- The development of disease resistance in muskmelons has been chiefly concerned with resistance to powdery mildew, which about 1925 began to cause extreme losses on melons in the Imperial Valley of California. Control of the mildew could be secured by application of sulfur but most varieties were so badly injured by it that sulfur could not be used effectively. Varieties resistant to mildew or to sulfur offered the only solution of the problem. A large number of native and foreign varieties were tested for resistance to mildew. In 1928 evidence of high resistance was found in certain virtually inedible varieties from India.

These were crossed with commercial varieties and in 1932 the first mildew-resistant variety, No. 50, was introduced. It was derived from a cross with Hale Best and represented a most valuable accomplishment in breeding. Further breeding work resulted in the development of an improved variety, Hales No. 45, which was of excellent quality and protected the industry from losses from mildew until 1938, when a new strain of the mildew fungus, Race 2, appeared. Since varieties resistant to Race 1 were susceptible to Race 2, further breeding work had to be undertaken. It proved possible to develop varieties resistant to Race 2, and between 1943 and 1946 two resistant varieties were introduced. One of these, Powdery Mildew Resistant Cantaloup No. 5, has since been very generally used, although Powdery Mildew Cantaloup No. 6 is also grown.

In the course of the work on mildew resistance various pathological investigations have been made in relation to resistance. The reaction of 21 species in the Cucurbitaceae to artificial infection with powdery mildew has been determined (1945), and there have been studies of correlated resistance in leaves, cotyledons, and stems of muskmelon. In 1942 it was shown that the addition of Vitamin B_1 to the soil in some way increased the growth of the powdery mildew fungus on cantaloups, although it could not be determined whether this was because of a direct effect on the parasite. When excised inoculated leaves were maintained on a sucrose solution to which Vitamin B_1 had been added, no significant effect on mildew development occurred. At the present time work is in progress on development of mildew-resistant Honey Dew and Honey Ball types of melons and further development of high-quality resistant cantaloups.

The increasing severity in losses from mosaic on cantaloups in the Imperial Valley has led to a search for simply inherited and potent resistance to the complex of three mosaic viruses that affect the crop. A number of mosaic-tolerant and mildew-resistant forms of inedible melons have been found and are being tested in hybridizing with commercial varieties.

Work on disease resistance in watermelons has resulted in the development of a variety Congo (1949), which possesses a certain degree of resistance to anthracnose, is a good shipper, and is of exceptional quality.

LETTUCE -- Breeding for disease resistance in lettuce has largely been concentrated on brown blight and downy mildew. Brown blight, a soil-borne disease of unknown cause, appeared in southern California and Arizona about 1918 and by 1923 had caused serious alarm. In 1923, 100 varieties of lettuce were grown on infested soil and only two, Big Boston and Chevigne, remained disease-free. Second-generation plants of a Chevigne x New York cross showed an approximate 3:1 segregation for resistance. Later, resistant plants were found in a badly diseased field of variety New York and selections were made from these plants. Eventually the resistant progeny of one such plant was released (1926) as the variety, Imperial No. 2.

Lettuce downy mildew also was cuasing losses in the same area. It was demonstrated (1924) that four races of the fungus existed. A variety of European origin was found to be highly resistant to the disease. By crossing this variety with several strains of New York it was possible to produce desirable varieties of the New York type resistant to the four known races of mildew. These also were released under the name Imperial followed either by a letter or a number, a system which has been continued with later introductions. In 1932 another physiologic race (Race 5) of the downy mildew fungus appeared, and all of the strains of lettuce resistant to the other races were attacked by it. In a series of extensive tests, two primitive and commercially useless European varieties proved immune and were used in the development of new strains of resistant lettuce. It was found (1940) that resistance to Race 5 and one of the other 4 races was controlled by a single dominant gene. Indirect evidence was thought to suggest the origin of new races of the fungus through mutation. Later investigations have dealt chiefly with the development of varieties of improved quality and increased resistance.

ONION -- The earlier work on disease resistance in onions dealt to a considerable extent with the nature of resistance to onion smudge (Colletotrichum circinans (Berk.) Vogl.), which is not highly destructive but causes slow shrinkage and injures the appearance of onions in storage. Studies (1920) demonstrated that, in yellow and red varieties which are resistant to the attack of the fungus, the watery extracts from the dry outer scales of colored varieties prevented germination and caused the rupture of the germ tubes of spores of the fungus. Extracts from white outer scales supported a normal growth of the organism. When the outer scales were removed spore germination occurred normally on the fleshy inner scales in both white and colored varieties and there was no exclusion of the fungus. Resistance was, therefore, expressed only in the outer dry scales and was associated with the coloring materials in the yellow and red varieties. Chemical studies of the toxic extracts from the scales resulted in the identification and isolation (1929-1935) of two phenolic compounds, protocatechuic acid and catechol, which are water-soluable and responsible for the resistance in colored outer scales. This work represented the first identification and isolation of a definite chemical substance responsible for resistance to a plant disease.

In recent years the onion investigations have included studies of resistance to pink root (*Phoma terrestris* Hansen), smut (*Urocystis cepulae* Frost), and smudge. Studies have been made of smut resistance in hybrids of *Allium* spp. (1944), factors affecting pathogenicity in pink root (1948), and the reaction of onion varieties to isolates of the pink root fungus (1948).

SWEETPOTATOES -- Research on disease resistance in sweetpotatoes has dealt chiefly with resistance to *Fusarium* wilt. Trials made as early as 1914 showed that certain varieties possessed varying degrees of susceptibility to wilt. Later tests (1927), conducted with 21 varieties over a period of four years, demonstrated that while all the popular table type varieties were very susceptible, certain other varieties showed considerable resistance.

After 1938 work was started on the development of varieties of superior horticultural type which also possessed resistance to wilt. In the course of work on production of varieties with high starch content for commercial use, evidence of wilt resistance was found in certain lines and these were used as parental material in the breeding of table stock. One variety, Allgold, which shows a certain degree of resistance to wilt has been introduced. Numerous seedling selections possessing more or less resistance to wilt, but not yet released as varieties, are being tested for eating quality and cultural characteristics. In more recent work, highly resistant parental stocks have been found in material from foreign countries. Certain Japanese varieties possess high wilt resistance and a very recent introduction from Tinian Island in the Pacific is very highly resistant and transmits the resistant character well to hybrid progenies. Work is now in progress on the development of varieties through hybridization with these stocks. The work has been facilitated by the development of methods for greenhouse testing for resistance.

TOMATO -- Work on disease resistance in tomatoes began in 1915 and for some years was concentrated on the development of varieties resistant to *Fusarium* wilt, which was causing increasing losses in the South. Between 1917 and 1922 a number of varieties were introduced that possessed considerable wilt resistance. In one of these, Marvel, wilt-resistance was exceptionally high and uniform. Between 1918 and 1928 nailhead spot had become increasingly serious as a disease of tomato fruits and threatened to destroy the tomato shipping industry in Florida. Marvel, which had shown striking resistance to fruit infection by the nailhead spot fungus, was crossed with Globe, which had the horticultural qualities desired by southern growers but was very susceptible to the disease. As a result, the variety Marglobe, which possessed high resistance to nailhead spot and also was highly tolerant of wilt, was introduced (1925). Its introduction saved the shipping industry in the South, and until the appearance of Rutgers (1934) it was the most important tomato variety. Later, Break O'Day, Pritchard, and Glovel, the last a "sister" of Marglobe but with pink fruit, were introduced. These varieties were all resistant to *Fusarium* wilt and to nailhead spot.

In further work on resistance to wilt a method was devised (1941) whereby large numbers of seedling plants were rapidly tested for resistance in the greenhouse. This method, which included the use of high virulent isolations of the wilt *Fusarium*, made it possible to subject plants to a much more severe test for resistance than had been possible in the field. Using this method it was found that a strain of the red currant tomato (*Lycoperiscon pimpinellifolium* (Jusl.) Mill.) from Peru was practically immune to wilt infection. Inter-specific crosses were obtained with Marglobe and by backcrossing and selection a variety, Pan America, was produced (1941), in which resistance to wilt was so high as to approach immunity. While Pan America has not had wide commercial use, it has been of great value in incorporating wilt-resistance in other varieties developed for resistance to various tomato diseases. In 1949 a yellow tomato of high wilt-resistance, Sunray, also was introduced.

In the course of pathological investigations on resistance to *Fusarium* wilt, it was shown (1945) that when Pan America scions were grafted on stocks of the susceptible variety Bonney Best a considerable percentage of the Pan America tops developed symptoms of wilt. When Bonny Best scions were grafted on stocks of Pan America, 90 percent of the tops remained healthy. It appeared that the factor for resistance to *Fusarium* wilt was confined to the root and was not transportable to the tops.

In other work (1945), in cooperation with the Bureau of Agricultural and Industrial Chemistry, a substance extracted from tomato plants was found to inhibit the growth of spores of the wilt fungus in culture. This material, known as tomatin, was present in nearly equal amounts in both resistant and healthy varieties, although slightly more was present in plants of the highly resistant species of *Lycopersicon pimpinellifolium*. It was found that the tomatin content was highest in leaves, with less in the roots, and very little in stems or fruits. Plants affected with *Fusarium* wilt showed a decreasing tomatin content as the disease progressed, while plants wilting and dying from mere lack of water showed no comparable decrease. The material in the plant extract has been found to be a glycosidal alkaloid. The relation of this substance to resistance to wilt has not yet been definitely determined.

In 1937-1938 the Division of Foreign Plant Exploration and Introduction collected a large number of strains of nearly all wild species of *Lycopersicon* in South America. This material has been extensively tested and has proved of great value, since several of the species have been found to be resistant to various tomato diseases. It has been found that *L. hirsutum* H. & B. is resistant to *Fusarium* wilt and also to leaf infection by *Alternaria solani*. Another species. *L. peruvianum* (L.) Mill., also has *Alternaria* leaf spot resistance. Crosses between *L. hirsutum* and cultivated tomatoes are readily obtained, but hybridization with *L. peruvianum* has presented great difficulty. However, such an inter-specific cross was secured (1945) and has since been used in studies on resistance to *Alternaria* leaf spot. Strains of *L. pimpinellifolium* also have been found showing resistance to this disease. Work is now in progress on the development of varieties possessing resistance to wilt, *Alternaria* leaf spot and stem canker, and to leaf infection by *Stemphylium solani* Weber. Resistance to *Alternaria* stem canker has been secured in several lines and some degree of resistance to leaf infections. Testing for resistance to stem canker and foliage infections has been facilitated by a method of dipping seedling tops and stems in a suspension of macerated fungus mycelium and then holding the plants in a moist atmosphere for 48 hours. A variety, Southland, introducted in 1948 possesses high resistance to *Alternaria* stem canker and *Fusarium* wilt. It also possesses a moderate degree of resistance to *Alternaria* leaf spot and to one form of late blight, although it is not resistant to other forms of the latter disease.

Two varieties of tomato, Riverside (1937) and Essar (1939), have been produced which possess some resistance to both *Verticillium* wilt (*Verticillium albo-atrum* Reinke & Berthold) and to *Fusarium* wilt. These varieties were developed for use under California conditions. In later work it was found that a strain of the red currant tomato and also one of the "cherry" type showed high resistance to *Verticillium* infection. Hybrids with the cultivated tomato gave progenies showing resistance, and continued selection and outcrossing gave resistant plants with fruits of marketable size. However, resistance has been coupled with low yields and late ripening and the work is still in progress. Recent development of a method for testing large numbers of seedlings in the greenhouse is speeding the work of selection and breeding, and certain selections now appear to have fair fruit size and earliness.

In breeding for resistance to curly top the early work yielded no evidence of resistance in a very extensive collection of foreign and native varieties of the cultivated tomato. A semi-wild, small-fruited Mexican type showed some resistance but in several years of crossing and selection it was found that this resistance could not be increased to where it was likely to be of great value. Tests with wild species from South America demonstrated that strains of *Lycopersicon peruvianum* var. *dentatum* Dun. and *L. glandulosum* C. H. Mul. were highly resistant though not immune to curly top. Crosses could not be obtained directly with these species and *L. esculentum*, but the cross *L. esculentum* x *L. hirsutum* was made and the progeny was crossed with *L. peruvianum* v. *dentatum*. The resulting progeny had very small fruit, and as fruit size increased resistance tended to decrease. For some years the work of selection was limited by the necessity of testing for resistance in the field at locations where consistent severe curly top infection was assured. Recently (1949), a method of greenhouse testing has been devised by which thousands of seedlings can be eliminated as effectively as under field conditions. This has greatly speeded the work of selection for resistance in a large population of selected progenies. The work is being continued and at present certain selections of most promise are being tested in the field in various localities where the disease occurs.

Investigations showed (1949) that some plants of *Lycopersicon hirsutum* possessed considerable tolerance of tobacco mosaic. Continued investigation resulted in the finding of two plants with extremely high resistance to mosaic. Hybrids of these plants and cultivated tomato varieties have given progenies some of which show high tolerance to artificial inoculation with the yellow and green strains of tobacco mosaic virus. It also has been found (1948) that they are less readily infected by natural means than commercial tomato varieties. Resistance has tended to be coupled with small fruit size but selections of resistant plants with fair-sized fruits recently have been secured.

CONCLUSION

This record of vegetable disease research in the Department of Agriculture is but a typical segment of the work of plant pathologist throughout the United States during the past fifty years. We have gained a substantial knowledge of fungus, bacterial, and virus diseases of vegetables and in many instances have developed means for their control. The advent of organic fungicides and insecticides holds further promise of reducing losses from certain diseases, hitherto difficult to control. Likewise, the period since 1925 has been marked by an intensive study of disease resistance. The striking success that has attended such work has served to stimulate the extensive program of work on disease resistance that is now in progress throughout the country.

DIVISION OF FRUIT AND VEGETABLE CROPS AND DISEASES, BUREAU OF PLANT INDUSTRY, SOILS, AND AGRICULTURAL ENGINEERING

INVESTIGATIONS ON POTATO DISEASES BY THE BUREAU OF PLANT INDUSTRY, SOILS, AND AGRICULTURAL ENGINEERING, UNITED STATES DEPARTMENT OF AGRICULTURE, 1910 to 1949

E. S. Schultz

The Irish potato is a favorable host for many fungus pathogens, including species from the slime molds to the smuts and rusts. It is also a favorable host for certain mosaic viruses, as represented by viruses A, X, and Y, and the yellows viruses causing leaf roll and witches'-broom. Certain nematodes also seriously affect potatoes. Most of the fungus pathogens invade the tops, as well as the tubers; others attack only the tops or only the tubers.

Though many diseases can infect the potato, rarely more than several diseases in a single season constitute limiting factors in potato production in any one locality. However, one disease like late blight can cause potato failure unless control measures are practiced.

In the Bureau of Plant Industry, Soils, and Agricultural Engineering, United States Department of Agriculture, investigations on potato diseases were initiated about 1910 by W. A. Orton, in charge of the Office of Cotton and Truck and Forage Crop Disease Investigations. These investigations have been continued by various staff members. During this period primary attention has been given to such diseases as wart, powdery scab, late blight, *Fusarium* wilt, *Fusarium* and bacterial rots, blackleg, bacterial ring rot, common scab, and virus diseases.

LATE BLIGHT: Late blight, one of the serious potato diseases where favorable moisture and temperature prevail, was one of the first diseases to receive major attention. In 1861 de Bary first recorded experimental evidence that the late blight fungus, *Phytophthora infestans*, is able to spread from infected seed tubers into the shoots and subsequently infect the foliage by spores from the infected shoots. Most investigators, following de Bary's work, failed to confirm his results. Other theories as to the yearly occurrence of late blight were that the mycelium overwinters in the soil; that resting spores are produced; that the mycelium is latent in the plant; that the fungus sporulates on the seed tuber in the soil, and the spores reach the surface of the soil and cause foliage infection; and that sclerotia-like bodies or a mycoplasm gives rise to infection. Inasmuch as considerable negative evidence on all but the perennial-mycelium theory had been presented, investigations were initiated on the perennial-mycelium hypothesis.

Investigations on the life history of the late-blight fungus conducted in the greenhouse and field disclosed that tubers infected with late blight from which sprouts become invaded by the fungus hyphae are the primary source for infection of potato tops in commercial potato fields.

Observations on primary infection of potatoes in potato fields in Aroostook County, Maine, showed that potato cull or waste piles, harboring late blight tubers, are primary sources for initiating late blight infection in commercial potato fields. Fields near potato waste piles are the first to become infected with blight and frequently become infected when the plants emerge and before spraying with fungicides commences. Potatoes harvested from fields infected with late blight before the foliage is killed by frost or by other means have confirmed earlier observations that over 50 percent of the tubers may become infected with late blight at harvest.

Observations on the reaction of different European and American potato varieties to late blight indicated that some varieties were more blight-resistant than others. Later work has shown that apparently blight-immune varieties can be developed and that the late blight fungus involves several races so that a variety immune from certain races is not necessarily immune from all races.

POWDERY SCAB: Investigations on the life history, occurrence, and control of powdery scab were begun in 1914 when, on account of this disease, a Federal quarantine was declared against Canada and Maine. The investigations on powdery scab disclosed that this disease was favored by heavy, wet soil in the cool, northern potato regions and that it was rarely developed to a serious degree in the South.

Studies on the life history of *Spongospora subterranea*, the cause of powdery scab, disclosed that a uninucleate spore in germinating produces an amoeba, that the potato tissue is first invaded by the fungus in the plasmodium stage, that the plasmodium invades the tissue between the cells, as well as penetrates the cells, and that the cell walls in contact with the plasmodium are somewhat swollen and show special affinity for the orange-G stain.

Several saprophytic and parasitic fungi were found to be associated with dry rot that secondarily involved many powdery scab lesions. Among them a species of *Phoma*, a wound parasite, occurred frequently. Growths resembling nematode galls or legume nodules were found on potato roots, generally appearing before tuber infection occurred. Roots of tomato and several other solanaceous plants were found to be susceptible to powdery scab.

Though none of the control measures used absolutely inhibited powdery scab, seed-potato treatments with mercuric chloride and formaldehyde reduced seed-borne infection, and sulfur at the rate of 900 pounds per acre reduced infection from the soil.

POTATO WART: The discovery of potato wart in the United States in 1918 by J. G. Sanders created an interest in studies on wart, which was regarded as a menacing disease. Though comprehensive investigations on the life cycle of the potato wart fungus, *Synchytrium endobioticum*, had been made by Percival and Curtis in England, it appeared desirable to investigate the pathological anatomy and the environmental conditions, such as moisture, temperature, soil reaction, etc., under which potato wart develops.

Anatomical studies disclosed that the wart can be considered a foliar branch system. It is a homoplastic growth with quantitative reduction in vascular tissue and increase in storage parenchyma. There is a complete but gradual transition from normal to wart tissue. Although wart shows both qualitative and quantitative reduction of tissues, there exists, nevertheless, a marked similarity between structure of normal host and wart.

Investigations on the influence of environmental conditions on the wart fungus and infection showed that a vigorous growth of the potato plant favored infection; water is essential for germination of soral and resting sporangia, as well as for dissemination of the motile cells; intermittent flooding and aeration are most favorable for germination; infection from soral sporangia occurs between near 0° and 30° C.; with variable soil temperature infection occurs when the mean is about 21° C.; and the soil reaction most favorable for infection ranges from about pH 3.9 to pH 8.5. Only certain solanaceous plants were susceptible.

Studies on the reaction of different American potato varieties to wart were made to ascertain whether differences in varietal resistance appeared such as were found among British potato varieties. Irish Cobbler, Spaulding Rose, McCormick, Burbank, and Green Mountain were found to be immune, whereas Triumph, Early Rose, Early Ohio, Rural, Pearl, American Giant, and Up-to-Date are susceptible. As immunity from wart appears to be constant in certain potato varieties and is heritable in a definite manner, the use of wart-immune varieties ensures effective control of this disease.

TUBER ROTS: Reports from potato growers, dealers, transportation companies, consumers, and the Food Products Inspection Service of the Bureau of Markets, United States Department of Agriculture, indicated that considerable loss resulted from potato tuber decay. As a result, cooperative studies were begun by the Inspection Service of the Bureau of Markets and by pathologists of the Bureau of Plant Industry. Under this program investigations on the causes and control of potato-tuber rots and losses appearing in storage, transportation, and marketing were conducted.

The results of these investigations disclosed that: *Fusarium* tuber rot was one of the primary causes of losses in storage; handling injuries resulting in cuts, bruises, and skin abrasions are primary sites of *Fusarium* rot; frost injury and late-blight rot are also followed by *Fusarium* rot; sunscald and freezing injury followed by slimy soft rot are responsible for major potato tuber losses in transportation and marketing; late blight tuber rot causes considerable loss in storage and on the markets; refrigeration during transportation and storage greatly reduces tuber rots; and careful handling in harvesting, storing, transporting, and marketing to prevent mechanical injury is essential to control storage rots.

Investigations on wound cork formation in potato tubers confirmed earlier findings that moisture and temperature are closely associated with suberization and periderm formation, and that the origin of decay at the central portion of the exposed surface of cut tubers is correlated with the slower healing of this tissue when compared with that of the periphery. Seed-piece decay increases in direct proportion to the degree of drying; water loss retards cork formation and favors fungus invasion.

In addition to causing tuber rot some *Fusarium* species also cause wilt. Although some workers claimed that infected seed tubers were an important source of infection, observations in certain irrigated areas indicate that soil infestation is the primary source of seed-piece and root infection with *Fusarium oxysporum*. Suggested methods for control of *Fusarium* wilt include long rotations, planting whole seed potatoes, and use of resistant varieties.

Studies on vascular discoloration of potato tubers disclosed that discolored bundles were often sterile, whereas apparently normal tissues frequently yielded parasitic fungi. Of 3,043 platings made from discolored tissues, only 58 percent gave fungus growth; and the organisms found, in descending order of frequency, were *Fusarium*, *Alternaria*, bacteria, *Verticillium*, *Penicillium*, *Colletotrichum*, *Rhizoctonia*, and miscellaneous organisms.

Investigations on the etiology of potato-stem lesions have shown that certain strains of

Rhizoctonia, several parasitic species of Fusarium, as well as Alternaria, Botrytis, Sclerotinia, Zygorhyrnchus, Corethropsis, Phoma, Clonastachys, and Acrostalagmus can cause lesions on potato stems.

COMMON SCAB: The common scab fungus, Streptomyces scabies, is harbored by certain soils throughout the potato areas of the world. Infected tubers also harbor the scab fungus in the corky lesions and thus serve as a source of infection for the new crop. The scabby lesions mar the appearance of the tubers, contribute to waste in peeling, and disqualify infected tubers for first-class grades of table or seed potatoes.

Studies on the scab fungus have shown that a number of strains of this organism exist in the soil. Cultural studies revealed that some isolates mutate more than others and differ in type and color of mycelium and in color of pigment produced in the medium. Color of mycelium or medium appears to be related to degree of parasitism. Mutation of the fungus did not appear to be affected by hydrogen-ion concentration, temperature, or nutrients. Although the reaction of a variety may vary with the strain of the scab fungus, studies on scab resistance in potatoes indicate that this resistance is relatively stable.

Inasmuch as seed-potato and soil treatments have not been generally satisfactory for control of common scab, and experience has shown that varieties vary in their reaction to the common scab fungus, investigations on breeding potatoes for resistance to common scab were initiated in 1930 under the National Potato-Breeding Program. These breeding studies have disclosed that many varieties manifest marked scab resistance. As a result of this work and that of State agricultural experiment stations the scab-resistant varieties Menominee, Ontario, Cayuga, Seneca, and Yampa have been developed as commercial varieties.

SEED-POTATO TREATMENTS: Seed-potato treatments for the control of such tuber-surface borne diseases as common scab and Rhizoctonia canker have been used and generally recommended. The earlier work indicated that formaldehyde controlled blackleg, whereas corrosive sublimate was more effective against Rhizoctonia. Though these treatments appeared effective in some areas, they did not give generally satisfactory results. In view of this experience, and with the availability of newer products like the organic mercuries that were developed during the first World War, the desirability of further studies on seed-potato treatments was indicated.

Seed-potato treatments with clean and Rhizoctonia-infected Irish Cobbler were conducted in northern Maine from 1925 to 1933 to ascertain the effect of different disinfectants on disease control, yield, and soil infestation.

The results of these tests showed that corrosive sublimate was one of the most effective treatments for Rhizoctonia control; certain organic mercury compounds also gave good control; treating seed potatoes heavily infected with Rhizoctonia significantly increased the yield; in two of the nine seasons when seed-piece decay appeared, certain treatments effectively controlled seed-piece decay; treating clean seed did not affect the yield; and certain soils are free from Rhizoctonia infestation. Selecting Rhizoctonia-free seed potatoes and planting them on clean soil results in Rhizoctonia-free potatoes even in the absence of seed-potato treatment.

VIRUS DISEASES: Potato diseases described as a "curled disorder of potatoes" were recognized early in the nineteenth century, but apparently did not begin to attract serious attention until early in the twentieth century, when leaf roll appeared in epiphytotic outbreaks in important potato areas of Europe. During this period hypotheses as to the cause of leaf roll and similar diseases were as numerous as the workers. Some of the early workers held that leaf roll was caused by fungi, but after about 1914 most of the workers on leaf roll and similar diseases began to regard them as non-parasitic and heritable; i.e., transmitted from one generation to the next through the tubers.

Mosaic on potato was observed by W. A. Orton in 1911 in a field at Giessen, Germany. In extended surveys throughout the leading potato areas in the United States during the growing seasons of 1912 and 1913 he found leaf roll, curly dwarf, and mosaic on certain potato varieties. In his 1912 survey in Maine, Orton observed fields of Green Mountain that had practically 100 percent mosaic, whereas other fields had less than 10 percent of the plants affected by mosaic.

Though the causal agent, the means of spread, and the types of mosaic, leaf roll, curly dwarf, and mosaic were obscure, Orton in 1914 recorded a diagnostic description of these potato disorders that he termed leaf roll, curly dwarf, and mosaic. As an effective control for these diseases he recommended the use of disease-free seed potatoes to be selected as a result of field inspection under a program of seed-potato certification by the seed-potato-producing States.

Intensive investigations on the nature, means of dissemination, and control of virus diseases of potatoes were initiated by the Bureau of Plant Industry, Soils, and Agricultural Engineering during the second decade of the twentieth century. At this time, none of the potato virus diseases had been experimentally transmitted from diseased to healthy plants, although observations indicated that leaf roll was harbored by tubers from plants infected with leaf roll. Mosaic was regarded as being caused by a single virus and associated with progressive deterioration of the affected plants from season to season.

Before the potato virus diseases were transmitted artificially, some workers held that the causal agent invaded the seed piece from the soil, whereas laymen held that the weather was the causal agent. Senescence, physiological deterioration, and other ideas involving the concept of "running-out", supplied additional conjectures regarding the causal agent.

Early observations disclosed that the yield from virus-affected potatoes was 25 to 60 percent lower than that from healthy seed potatoes. This loss in yield indicated the importance of conducting investigations on potato virus diseases. About 1917, when intensive studies on potato virus diseases were begun by this Bureau, many potato fields in important seed-potato-producing areas manifested 50 to 100 percent mosaic-affected plants, and a considerable number of fields had over 50 percent of the plants infected with several virus diseases, resulting in dwarfed, curled, mottled, rolled, and streaked plants. Later this condition was found to be caused by composite infection with leaf roll, spindle tuber, and different mosaic viruses.

Inoculations by means of leaf-rubbing and grafts showed that different varieties did not necessarily react the same to the same disease. This experience led to the use of a single variety, the Green Mountain, as host for studies on virus isolation and identification.

As aphid transmission had been demonstrated for mosaic in tobacco, spinach, and cucumber, studies with potato aphids were made in the greenhouse and under cloth cages in the field. These studies disclosed for the first time that potato mosaic, leaf roll, and spindle tuber were transmitted by aphids. Comparative studies on the transmitting potency of Myzus persicae, M. circumflexus, M. solani, and Macrosiphum solanifolii disclosed that all four aphid species transmitted leaf roll, rugose mosaic, crinkle mosaic, and mild mosaic, but M. solanifolii was less effective as a vector of leaf roll than the other three species. Observations showed that M. solanifolii fed much less consistently in the vascular tissues than did the other species, which circumstance may be related to efficiency in transmission of leaf roll.

These potato virus infection studies revealed composite infection, i.e., mosaic + leaf roll + spindle tuber and mosaic + necrosis, as well as apparently single-virus infections. From the apparently single-virus infections, isolation plant cultures were propagated under insect-proof cages.

The performance of these isolation cultures, as well as of comparative single-virus plant selections from the field, revealed, upon propagation in isolation under cloth cages, that mosaic-affected plants did not deteriorate progressively from year to year, but remained stable, which was contrary to the former view.

Furthermore, the isolation studies led to the recognition of mild mosaic, leaf-rolling mosaic, and rugose mosaic, and later latent mosaic in the Green Mountain variety. When healthy seedling potato varieties were grafted onto apparently healthy Green Mountain most of them manifested foliage and apical stem necrosis, which showed that the apparently healthy Green Mountain harbored a mosaic virus, and this was termed latent mosaic. It was further determined that latent mosaic was a component of each of the mild, leaf-rolling, and rugose mosaic viruses. Under the system of designating potato viruses by using letters, latent mosaic is caused by virus X, mild mosaic by viruses A + X, and rugose mosaic by viruses X + Y.

An interesting abnormality of potato distinguished by "staring", sparse, erect, and somewhat dwarfed tops and typically spindle-shaped tubers, regarded by some observers as "physiological degeneration", was shown for the first time to be transmissible by grafting, leaf rubbing, and insects. The typically spindle-shaped tubers suggested the name spindle tuber for this potato virus disease.

The identification of spindle tuber as one of the potato virus diseases led to an understanding of certain so-called curly-dwarf potato plants that resulted from composite infections of spindle tuber +mosaic + leaf roll, as well as from dwarfing strains of the spindle tuber virus.

In connection with the studies on potato leaf roll an internal tuber discoloration termed net necrosis was identified as a tuber reaction to the leaf roll virus, which developed only in certain varieties, like Green Mountain, and only as a result of current-season infection of healthy plants with the leaf roll virus. It materially adds to the potato losses due to severe reductions in yield that result from leaf roll attack.

Anatomical studies on internal necrosis of potato disclosed that necrosis was associated with more than one disease. Necrosis is a diagnostic symptom of potato leaf roll when restricted to the phloem and occurring in stolons, tubers, and the tops of the plants.

Effect on Yield. -- Studies showed that mild mosaic reduced the yield of Green Mountain 25 to 30 percent; rugose mosaic reduced it 50 to 70 percent; spindle tuber, 30 to 35 percent; and leaf roll, 50 to 70 percent. The common race of the latent mosaic virus reduced yields 10 to 25 percent in some varieties. Since latent mosaic is generally harbored by the leading old varieties and by some of the new ones, it is reasonable to say that in the absence of latent mosaic yields would be increased at least 10 to 15 percent.

Isolated Seed Plots, and Early Harvesting. -- Insect transmission studies of potato virus diseases indicated that selection of apparently healthy hills in close proximity to virus-affected hills did not necessarily result in healthy seed potatoes, and that the percentage of healthy progeny increased as the distance from diseased plants was increased. This experience led to the use of isolated tuber-unit seed plots for control of potato virus diseases.

The tuber-unit method of planting facilitates detection of disease and the roguing of diseased hills. Studies on isolated tuber-unit seed plots located at different distances from virus-affected potato fields showed that when aphids were numerous, viruses spread to seed plots located several hundred feet from virus-affected potatoes, whereas healthy potatoes propagated in seed plots surrounded by woods and located a mile or more from diseased potatoes remained healthy.

Early harvesting of healthy plants from seed plots was initiated after experience had shown that roguing tuber-unit seed plots located within 1,000 feet of virus-affected potatoes did not insure 100 percent virus-free potatoes, though it did maintain the virus content in such rogued plots below 5 percent, whereas non-rogued fields of the same variety showed over 50 percent of virus diseases.

Harvesting tubers from apparently healthy hills located near virus-infected plants by taking one tuber from the same hill at weekly intervals from early in August to the middle of September had shown earlier that the earliest harvested tubers remained relatively free from disease, while the later harvested tubers produced many virus-diseased plants. This experience showed that virus infection of healthy plants increased as the season advanced.

In tests in Maine from 1932 to 1947, two varieties highly susceptible to virus diseases remained free from virus diseases when harvested about August 1, even though growing within 500 feet of diseased potatoes. Samples of these varieties harvested from the same plots September 15 developed 90 to 95 percent of mosaic and leaf roll in seasons when heavy aphid populations prevailed. This experience shows that susceptible potato varieties can be maintained free from virus diseases in some seed-potato-producing areas, even with meager isolation, if the seed potatoes are harvested very early in the season before the dispersal of virus-carrying aphids begins.

Varietal Resistance. -- Studies disclosed that different potato varieties vary in their reaction to the same virus disease. Some varieties react to the mosaic viruses by manifesting distinct mottling; others by slightly light green and rugose foliage; others by necrosis; and still others are carriers without apparent symptoms. Some varieties are highly resistant, while others are immune from certain mosaic viruses. The earlier field observations on mosaic in commercial varieties disclosed that the Green Mountain manifested a materially higher percentage of mosaic plants than Irish Cobbler. Inoculations with mild mosaic by means of aphids and leaf rubbing later showed that Irish Cobbler is immune from the virus A component of mild mosaic.

While studying the reaction of different varieties to the mild, rugose, and latent mosaics it was discovered that one of the potato seedling varieties contracted viruses A and Y, components respectively of mild and rugose mosaic, but did not contract virus X, the cause of latent mosaic. Subsequent studies with this seedling proved it to be immune from virus X, which is harbored generally by the older and some of the newer potato varieties.

Different varieties vary in their reaction to virus A component of mild mosaic as follows: distinctly mottled; slightly rugose and light green; top or apical necrosis; carriers with no apparent symptoms; those that contract infection more easily than others; and immunity. The varieties immune from virus A apparently fall into two groups: (1) Varieties that are immune by aphid infection but contract the virus by graft infection and produce mottled leaves, and (2) Varieties that are immune by aphid infection but in grafts develop necrotic local lesions, a hypersensitive reaction, where virus A apparently is inactivated.

Investigations on the reaction of varieties to virus X, the other component of mild mosaic, have disclosed that varieties differ in their reaction as follows: foliage mottling; slightly rugose and light green; necrosis; carriers with no apparent symptoms; and graft-immune; as well as immune with other methods of inoculation, including contact with plants harboring virus X.

In grafts aerial tubers form on a scion harboring virus X growing on a stock immune from virus X, which indicates that carbohydrates as well as virus X are unable to pass from the infected scion into the immune stock. This aerial tuber reaction facilitates isolation of varieties immune from virus X in segregating progenies.

By using jimson weed, Datura stramonium, and other host plants it has been found that there are several races of virus X, as determined by their reaction on the host. The weak race induces apparently no perceptible reaction; the so-called more virulent races induce severe necrosis; whereas the intermediate races induce various degrees of mottling.

Protective inoculations have shown that a potato plant inoculated with one race of virus X is protected against infection by other races. Inasmuch as varieties that are very susceptible to virus X readily contract infection when exposed to varieties harboring the virus in commercial fields, such new varieties susceptible to virus X can be protected against infection from the more severe races if they are inoculated with the weak race, which apparently affects the yield less. Experience in 10 consecutive seasons has shown that a variety harboring weak virus X and growing in alternate hills with potatoes harboring a stronger virus X race did not contract a stronger race of virus X, whereas the virus-free controls contracted it in every plant or hill.

Investigations have shown that a variety immune from virus X is immune from all the races of virus X so far tested.

Studies on the reaction of different varieties to virus Y, a component of rugose mosaic, disclosed that many varieties react by developing foliage necrosis, manifested by necrotic spots on the leaves and necrotic streaking of veins, petioles, and stems, which is associated with brittleness and leaf drop; rugosity and a vein-clearing type of mottling also appear on some varieties, along with the foregoing reactions; some varieties manifest light green and rugose foliage to so slight a degree that they may be mistaken for healthy plants.

Varieties immune from virus Y have not been found, but some varieties are highly field-resistant, i.e., rarely contract virus Y; whereas other varieties under the same conditions become 100 percent diseased.

The isolation, identification, and methods of inoculation of potato viruses and studies on the reaction of different potato varieties to different types of mosaic viruses, spindle tuber, and leaf roll viruses facilitate the program for breeding potatoes for resistance to virus diseases. As a result of this breeding work, potato varieties have been developed that harbor immunity from two major mosaic viruses and high field resistance to a third important mosaic virus. Moreover, some varieties immune from mosaic also are highly field-resistant to the other two important mosaic viruses, as well as to leaf roll. For instance, Katahdin, the first variety named under the National Potato-Breeding Program, is immune from virus A and field-resistant to viruses X and Y and to leaf roll. Chippewa, the second variety named under this program, is immune from virus A and very highly field-resistant to virus Y.

The use of these varieties immune from mosaic, together with other resistant varieties, has contributed towards progress in potato production and improvement and has facilitated control of important potato mosaic diseases.

SUMMARY OF ACCOMPLISHMENTS IN POTATO DISEASE INVESTIGATIONS BY THE BUREAU OF PLANT INDUSTRY, SOILS, AND AGRICULTURAL ENGINEERING, 1910 to 1949:

1. In 1911, W. A. Orton was impressed by the results of seed-potato inspection and certification in Germany during his visit to that country. He succeeded in initiating seed-potato certification in the United States through conferences with State representatives of the potato industry and through publications. Undoubtedly seed-potato certification ranks first among the agencies that induce growers to produce disease-free seed potatoes.

2. Studies on powdery scab showed that the disease was favored by environmental conditions in certain northern potato areas but it was not a limiting factor in southern potato regions; and that soil and seed-potato treatments did not entirely inhibit this disease.

3. Investigations on hibernation of the late blight fungus disclosed that infected tubers harbor the late blight mycelium which invades the young shoots, on which the fungus sporulates and thus initiates infection of potato fields. These results confirmed de Bary's observations on the perennial mycelium that had been questioned by later workers. Potato cull piles with tubers infected with late blight were found to be major reservoirs for initial infection of commercial potato fields. Investigations show that blight-immune varieties can be developed, and that, as other workers found, the late blight fungus represents several races, so that an apparently blight-immune variety is not necessarily immune from all races of the late blight fungus.

4. Studies on resistance of potatoes to common scab disclosed that certain varieties are highly resistant to this disease.

5. Studies on resistance of potatoes to bacterial ring rot have disclosed that certain varieties are highly resistant to this disease.

6. Studies on potato wart disclosed that intermittent flooding and aeration are most favorable for spore germination; with variable soil temperature, infection occurs when the mean is about

21° C.; the most favorable soil reaction range is about pH 3.9 to pH 8.5; and that on the basis of resistance, potato varieties that fall into the same natural group react similarly to wart. In general, the Irish Cobbler, Spaulding Rose, McCormick, Burbank, and Green Mountain types are wart-immune, whereas the Triumph, Early Rose, Early Ohio, Rural, Pearl, American Giant, and Up-to-Date are susceptible.

7. Studies on potato tuber rots disclosed that cuts, bruises, skin abrasions, sunscald, freezing injury, and late blight infection predispose potato tubers to decay-producing organisms and that careful handling during harvesting, storing, transporting, and marketing to prevent mechanical injury is very essential for preventing tuber rots.

8. Experience with seed-potato treatments for control of tuber surface-borne diseases has shown that corrosive sublimate and certain organic mercuries controlled Rhizoctonia canker; treating seed potatoes that were heavily infected with Rhizoctonia significantly increased the yield; in some seasons seed-potato treatments controlled seed-piece decay; and treating clean seed potatoes had no adverse effect on yield.

9. Studies on so-called deterioration, or running-out, of potatoes showed that mosaic or leaf roll or combinations of these diseases, sometimes involving as high as 50 to 100 percent of the plants, were primarily responsible for potato deterioration.

10. For the first time inoculations by leaf rubbing, grafting, and aphids resulted in transmitting potato mosaic, whereas only grafting and aphids were effective in transmitting leaf roll.

11. Isolation, identification, and cultural studies with potato mosaic revealed that mosaic was not caused by a single virus that gradually reverted to more severe forms, but was a composite of several viruses.

12. Different potato varieties were found to give different reactions to the same mosaic virus, which indicated the necessity of using a single variety to identify and classify mosaic viruses.

13. A type of potato disorder characterized by erect, sparse, "staring" tops, and spindle-shaped tubers was shown to be a virus disease and was named spindle tuber. Spindle tuber in conjunction with certain mosaic viruses and leaf roll was found to be causatively associated with certain so-called curly-dwarf types of potato virus diseases.

14. Experience with selection of apparently healthy potatoes at different distances from virus-affected potatoes showed that the percentage of plants contracting virus infection decreased the farther they were from the diseased plants. This suggested the use of the tuber-unit isolated seed plot for control of virus diseases through use of clean seed.

15. Results from harvesting potatoes at different dates during the season showed that the percentage of virus infection increased with the advance of the season and suggested early harvesting of seed potatoes.

16. When virus-susceptible potatoes located within 500 feet of diseased potatoes were harvested about August 1 in Maine they were maintained free from virus diseases from 1932 to 1947.

17. Experience with the reaction of different potato varieties to mosaic showed that they vary in their symptomatology as well as in their resistance. Certain varieties are immune from some one of the three more common mosaic viruses A, X, and Y, but are susceptible to the other two mosaic viruses.

18. Varieties have been developed that are immune from virus A, as well as field-resistant to viruses X and Y and to leaf roll; some are immune from virus X; and others are highly field-resistant to virus Y.

19. Studies on isolation, identification, classification, inter-varietal reaction, and transmission of potato viruses have been essential in selecting and breeding potatoes for resistance to the various diseases.

20. Potato disease investigations have helped in the production of varieties resistant to major virus and fungus diseases, and work is in progress designed to develop a variety that has combined resistance to the major potato diseases and in addition has desirable horticultural characters.

21. The results obtained from investigations on potato diseases in the Bureau of Plant Industry, Soils, and Agricultural Engineering, United States Department of Agriculture, 1910 to 1949, are recorded in more than 200 publications, including technical bulletins, farmers' bulletins, circulars, and research journals. They contribute toward an understanding of the nature, life history, transmission, identification, and disease resistance and other methods of control of the major potato diseases. This information materially contributes toward increased yields and reduced waste and losses in harvesting, storage, transportation, and marketing, which serves to place the potato industry on a fundamentally sound economic basis.

DIVISION OF FRUIT AND VEGETABLE CROPS AND DISEASES, BUREAU OF PLANT INDUSTRY, SOILS, AND AGRICULTURAL ENGINEERING

FIELD AND LABORATORY RESEARCH ON THE DISEASES OF HARDY FRUIT CROPS CONDUCTED BY THE UNITED STATES DEPARTMENT OF AGRICULTURE 1885-1950[1]

John C. Dunegan

INTRODUCTION

The need for investigations on the diseases of fruit crops was one of the first problems confronting the newly established Section of Mycology organized on July 1, 1885 in the Botanical Division of the Department of Agriculture, with F. L. Scribner as the first mycologist. During the 65 years which have elapsed since this section was established many fruit diseases have been investigated and, for the most part, satisfactory control measures developed, but some old and other newly discovered diseases continue to be serious threats to fruit production in the United States.

In reviewing the varied investigations on fruit diseases by Department workers over the 65-year period, it seems best to divide this period roughly into a series of decades and discuss the work and results which characterized each decade.

THE PIONEER PERIOD 1885-1900

At the present time, when fruit pathologists are greatly concerned with the virus diseases affecting deciduous fruit crops, it is interesting to note that Erwin F. Smith in 1886 was assigned the problem of investigating the destructive malady known as peach yellows. Thus, one of the first problems investigated in the Department on fruit diseases dealt with a virus disease and the paper published in 1888 by Smith on peach yellows still is one of the most comprehensive descriptions of this disease that we have. A second paper published by Smith in 1891, under the title "Additional Evidence on the Communicability of Peach Yellows and Peach Rosette," gave detailed information on the contagious nature of peach yellows and peach rosette, another disease which had been confused with peach yellows.

In 1889 Scribner was succeeded by B. T. Galloway who gathered around him a staff of young, competent, and enthusiastic investigators. One of these men, N. B. Pierce, published in 1900 a monographic study of another peach disease under the title "Peach Leaf Curl, Its Nature and Treatment." In this bulletin Pierce presented the results of his experiments which demonstrated conclusively that peach-leaf curl (Taphrina deformans) could be successfully controlled by dormant applications of either lime-sulfur or bordeaux mixture.

M. B. Waite, who joined Galloway's staff at this time, started his career of more than 40 years in Government service by investigating pear blight (Erwinia amylovora), a bacterial disease of pears and apples. He found that the disease was spread by insects depositing bacteria in the nectar of pear blossoms. Since this was the first demonstration of the insect transmission of a bacterial disease of plants, Waite gained international renown through this discovery.

Waite continued his study of the disease as it occurs in orchards in many parts of the country and by 1895 concluded that the only practical method of controlling the trouble was to cut out and burn every particle of blight when the trees were dormant, stating, "Not a single case of active blight should be allowed to survive the winter in the orchard, or within a half-mile or so of it." This removal of the source of overwintering bacteria is an arduous and expensive procedure but growers in the Pacific Coast States have adopted Waite's method and have been able to produce crops of pears for many years. The entire western pear industry stands as a monument to this fundamental work of M. B. Waite.

THE SECOND DECADE 1900-1910

By 1900 work in plant pathology was a well-established function of the Department of Agriculture and the staff was being organized on a more specialized basis. Waite was placed in charge of the Office of Fruit Disease Investigations and he, like Galloway in the preceding decade, enlisted a group of capable, young investigators. With the staff increased, the tempo of work was accelerated and diverse problems were attacked with the development of practical control procedures as the ultimate goal.

One of the major problems which confronted the staff in 1900 was the development of a satisfactory fungicide for use on peach trees during the growing season. The fungus diseases brown rot (Monilinia fructicola), and scab (Cladosporium carpophilum), were limiting factors in peach production; yet, when the growers attempted to control these diseases with bordeaux mixture, their efforts frequently resulted in excessive injury to the trees. The fungicidal properties of sulfur had been recognized prior to 1900 but the only spray preparation then available was liquid lime-sulfur solution, which often severely injured peach leaves and twigs when used during the growing season. In 1901 W. M. Scott, working with M. B. Waite, tested a series of sulfides but found that they, too, were extremely caustic. Within a few years, however, Scott was experimenting with a mixture of sulfur and stone-lime in which small quantities of water were added to the stone-lime. The heat resulting from the slaking of the lime produced a chemical reaction with the sulfur. Additional water was added, stopping this reaction before injurious calcium polysulfides were formed, with the result that an effective mixture of sulfur and lime was produced which was not injurious to peach foliage. Scott, in his original description of self-boiled lime-sulfur, notes that as early as 1833 a Dr. William Kendrick had prepared a crude form of this fungicide and had recommended it for the control of mildew on grapes, and that in 1885 William Saunders had produced a similar material by mixing sulfur and lime with boiling water, but it remained for Scott to demonstrate that an effective and safe summer-fungicide for peaches could be prepared through the use of stone-lime and sulfur. A preliminary account of these experiments with self-boiled lime-sulfur was published in 1908, and in 1910 Scott and T. W. Ayres published a full account of their experiments with self-boiled lime-sulfur. The marked control obtained with self-boiled lime-sulfur over the brown rot fungus and the peach scab fungus without producing injury gave a decided impetus to the commercial production of fresh peaches in the humid, eastern sections of the United States. In fact, the extensive plantings of peaches from Georgia to as far north as Michigan, New York, and Massachusetts were made possible only by this fundamental discovery.

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[1] Problems associated with the transportation and storage of hardy fruit crops are not considered in this summary.

In 1902 Erwin F. Smith announced the discovery of the new bacterial disease of Japanese plums in Michigan which he called the black spot disease. He isolated the organism in pure culture and was able to reproduce the disease by spraying suspensions on young, green plums. About this time numerous State investigators in the East were finding a disease on peaches likewise caused by a yellow bacterial organism but the symptoms on the fruit were not similar to those produced on plums by the organism Smith had discovered. The symptoms on the leaves, a typical leaf-spot effect, however, were quite similar and it seemed possible that the organism originally described on plum was also a serious parasite of the peach. J. B. Rorer, another investigator Waite had added to his staff, attacked this problem and by 1908 he was in a position to state that the organisms (now known as Xanthomonas pruni) attacking the plum and the peach were identical.

In 1905 Waite, while studying pear blight in California, had his attention called to a disease of peaches, almonds, and apricots producing a gummosis of the twigs and the death of many buds. This disease, caused by the fungus Coryneum beijerinckii, had been seen as early as 1898 in specimens from Ohio and had been mentioned by Pierce in his discussion of peach-leaf curl as being present in California. The production in some of the most profitable orchards had been reduced to one-half or even a quarter of the crop. Since this disease seemed most aggressive during the dormant period when the leaves were off the trees, it had been suggested that bordeaux mixture should be employed as a fungicide to control the trouble. California growers, however, reported that bordeaux mixture was quite ineffective, but upon questioning them, Waite found that the sprays were not applied until after the disease began to appear on the twigs. He immediately suggested that they apply the sprays in the late fall or very early winter before the disease became evident. He reported in 1906 that orchardists who had sprayed their blocks of peach trees with bordeaux mixture, in December 1905, stated in March of 1906 that there was no evidence of the disease in any of the trees even though one of the orchards had been severely injured in 1905. Furthermore, the growers left non-treated blocks and the disease in these blocks was even more severe than it had been in 1905. This demonstration of the proper time to use a well-known fungicide has been of fundamental importance to the growers of almond, peaches, and apricots in the Pacific Coast States.

Not all the work of the Office of Fruit Disease Investigations was confined to the investigation of peach diseases, for during this period Scott investigated the control of apple blotch (Phyllosticta solitaria) and apple bitter rot (Glomerella cingulata), two serious fungus diseases of apple orchards. Since self-boiled lime-sulfur had proved so effective for the control of peach brown rot and scab, it seemed obvious that the same materials should be tried for the control of apple diseases, but it was soon found that this material was only moderately effective against these apple diseases. It was also demonstrated that liquid lime-sulfur solution, which was effective against the apple scab fungus, did not yield satisfactory control of either the blotch or the bitter rot fungi. However, Scott, in a series of experiments conducted in Arkansas and other midwestern states, demonstrated that bordeaux mixture could be used for the control of these two diseases and he devised a spray schedule in which the use of bordeaux mixture was avoided in the early applications, thus reducing the amount of fruit russetting. Bordeaux mixture gave outstanding control results against these two fungi, but in some seasons and with certain varieties there was apt to be considerable russet of the fruit even when used as recommended by Scott. Elimination of russet due to the use of bordeaux mixture and the reduction of foliage injury from this same material was to prove to be a very vexing problem and the solution was not reached in the matter of copper injury until several decades later.

Fungus diseases and fungicides were not the only problems investigated by members of the Department dealing with fruit diseases during this interval. Waite, for example, began an extensive study of the effect of low temperatures on fruit trees. Some of his observations, published under the title "Fruit Trees Frozen in 1904," have been most helpful to growers who have had recurring low-temperature injury. One of the most fundamental concepts derived from this study of low-temperature injuries is the fact that trees injured during the winter are in what might be called a state of "shock" and should not be pruned immediately after the injury.

This interest in low-temperature injury to fruit trees became one of the abiding interests of Waite throughout the balance of his professional career and he was one of the first to suspect that the premature death of peach trees in the southern orchards was due to what he called the "southern type of winter injury." Waite noted that in the South there were marked fluctuations in the temperature during the winter with periods of 70° to 75° F. followed by abrupt drops within a few hours to temperatures below freezing. Under the influence of the high temperatures which frequently prevailed for several weeks in midwinter, cambial activity was started and drastic injury resulting in the death of many trees was the aftermath of the sudden drops in temperature.

W. M. Scott, after a series of experiments with self-boiled lime-sulfur for the control of apple diseases, instituted a series of experiments using lime-sulfur solution as a substitute for bordeaux mixture in the control of the apple scab fungus (*Venturia inaequalis*). A. B. Cordley, R. K. Beattie, E. Wallace, and C. Brooks reported that dilute lime-sulfur solution had given them good control of the apple scab fungus in the particular States where they were working. Since the use of bordeaux mixture early in the season is generally accompanied by pronounced russetting of the young apples, Scott and the other workers were very anxious to secure a substitute which would eliminate this injury. He reported in 1910 that liquid lime-sulfur solution could be satisfactorily substituted for bordeaux mixture in the treatment of apple scab and for the apple leaf spot commonly associated with the black rot fungus (*Physalospora obtusa*). It was soon noted, however, that liquid lime-sulfur will also produce, under certain conditions, injury to the leaves and at times even a sulfur-burning of the fruit. The problem of reduction of injury from liquid lime-sulfur continues to be a vexing problem even at the present time.

The cherry leaf spot fungus, *Coccomyces hiemalis*, producing a disease of the leaves which results in premature defoliation and even the death of the trees if allowed to continue for several years unchecked, was another problem which attracted Scott's interest during this decade. Among the materials which he tested were dilute lime-sulfur solution, self-boiled lime-sulfur, and bordeaux mixture. Some of his experiments with self-boiled lime-sulfur gave satisfactory control of the leaf spot fungus but continued experimentation demonstrated that either dilute liquid lime-sulfur or bordeaux mixture were the most satisfactory materials to use. Here again, the problem of injury from the use of fungicides was noted and it was soon discovered that bordeaux mixture could not be used with safety on sweet cherries, and under some conditions, lime-sulfur solution produced injury to the foliage.

C. L. Shear began his study of the fungus diseases of cranberries and published his first report on them in 1907.

Thus the decade 1900-1910 was one of marked progress. The scientific staff was expanding in the Department of Agriculture and pathologists had attacked with vigor problems of peach disease control, such as brown rot and scab; and apple diseases, such as apple scab, leaf spot, blotch, and bitter rot. They had experimented with a variety of fungicides, had devised a new form of self-boiled lime-sulfur, had worked out a method for the control of pear blight in the West, had demonstrated that *Coryneum* blight could be controlled by dormant spraying, had gained insight into the fundamental problems of response of fruit trees to low temperatures, and had shown that there was in the East a serious disease of peaches of bacterial origin. These achievements must be classed as outstanding, but at the same time, they had encountered the problem of spray injury. It was not sufficient, they found merely to control the fungus disease attacking fruit trees, but the control should be with materials that were relatively noninjurious to the host plant. Their solution of this vexing problem was not satisfactory and the matter of reduction of injury with the use of fungicides was one that was to attract the attention of Department and State investigators for many years to come.

THE THIRD DECADE 1910-1920

The outstanding results of the preceding decade served as a further stimulus to the work of fruit pathology in the Department and new additions were made to the staff, while some of the older workers left the Department to engage in other lines of activity.

During this period John W. Roberts demonstrated that the apple leaf spot, commonly called frogeye, was the result of an initial infection of the leaf by the black rot fungus followed by invasion of the dead tissue by weak parasites, particularly a species of Alternaria. He showed further that typical frogeye spots could be produced artificially by killing a small spot of leaf tissue and the Alternaria promptly invaded the dead tissue. This discovery made it clear that apple leaves injured by spray chemicals could subsequently develop a series of typical frogeye leaf spots even though there was little or no black rot present in the orchard.

Working in Arkansas, Roberts also investigated the problem of the overwintering of the apple bitter rot fungus and found that in orchards where the fungus was causing complete loss of the crops season after season it produced typical cankers on the twigs and smaller limbs. Subsequent investigators have been unable to find these bitter rot cankers, but it must be remembered that the majority of the orchards in recent years have been sprayed with bordeaux mixture and do not represent conditions similar to those studied by Roberts where the fungus had been allowed to grow unchecked over a period of years in the orchard.

Roberts also studied in Arkansas methods for the control of the peach bacterial disease which had been described by Rorer. He noted that the disease was most serious on trees in a poor state of vigor, or those growing in soils low in fertility, and he demonstrated that the disease could be held in check by proper cultural procedures and the judicious use of nitrogen fertilizer.

During this period G. W. Keitt, now at the University of Wisconsin, carried on extensive studies at Hart, Michigan, and Cornelia, Georgia, on the peach scab fungus. His monographic study appeared as a Department bulletin in 1917 and has long been accepted as a classic on the subject. One of the most important features of Keitt's study was the demonstration that the scab organism grows very slowly. The infections take place from 50 to 60 days before the spots become visible, and he showed that for proper control the first spray application should be made about one month after the petals have dropped. This is long before any symptoms of the disease appear on the fruit; but the commercial growers, universally, have accepted this finding and an application for control of peach scab early in the season is a standard procedure.

Shear discussed in 1915 the prevalence of grape anthracnose in the United States, and L. A. Hawkins reported the same year that the disease could be controlled by the use of a dormant spray of lime-sulfur followed by 4 or 5 applications of 8-8-100 bordeaux mixture during the growing season.

N. E. Stevens studied the correlation between climatic conditions and the prevalence of cranberry fruit rots in the United States, while Shear described an end rot of cranberries due to Fusicoccum putrefaciens, as well as false blossom disease of cranberries.

D. F. Fisher, W. S. Ballard, and W. H. Volk studied the control of apple powdery mildew in western fruit-growing districts. They found that the arid climate favored the development of the fungus Podosphaera leucotricha, and that the disease could be effectively controlled by the use of dilute lime-sulfur during the growing season. However, the use of this material in western orchards after the first of June was almost certain to cause severe injury to the fruit.

Shear, Stevens, R. B. Wilcox, and B. A. Rudolph investigated the fungi causing fruit rot after the cranberries were harvested.

Stevens continued his studies on fruit rots with a study of the pathological histology of strawberries affected by a species of Botrytis and Rhizopus.

THE DECADE 1920-1930

A serious outbreak of brown rot and plum curculio in the Fort Valley peach area during the 1920 season led to the establishment, in 1921, of a field laboratory at Fort Valley, Georgia. Extensive experiments for the combined control of brown rot, scab, and curculio were carried on during the years 1920 to 1924 by the Bureau of Entomology, Bureau of Plant Industry, and the Georgia State Board of Entomology. The writer was assigned to work at Fort Valley in 1921 on peach brown rot, scab, and bacterial spot. L. M. Hutchins also started his extensive studies at Fort Valley on the phony disease of the peach, as well as his studies on the southern type of winter injury and the delayed dormancy problem.

During this time Roberts and Dunegan initiated experiments on the control of blossom blight (Monilinia) and found that it would be necessary to apply a series of sprays during the blossom period for satisfactory control. Later work demonstrated that this original concept of the blossom blight control problem was essentially sound, but in the early '20s spray machinery was not available for the rapid application of sprays over extensive areas and the program was abandoned at that time as being impractical.

At this time extensive peach plantings were coming into bearing in the Sandhill region of North Carolina and it soon became evident that the cultural procedures and the use of nitrogen fertilizers for bacterial spot control, as recommended by Roberts in the preceding decade, would not yield satisfactory results in North Carolina. Roberts started experiments which eventually led to the development of the zinc-lime spray, prepared by adding a dilute solution of zinc-sulfate to a dilute solution of hydrated lime.

In a series of experiments at Vincennes, Indiana, Roberts and Leslie Pierce demonstrated that zinc-lime spray, carefully applied with particular emphasis on covering the underside of the leaves, would give a degree of control of the bacterial spot organism, both on the leaves and fruit, better than anything that had been previously tested. The final program required between five and seven spray applications made at intervals of two weeks. This was an arduous spray program, but the results were so outstanding in Indiana and elsewhere that the growers accepted the program and put it into commercial operation in many parts of the country.

With the termination of work on the brown rot problem at the Fort Valley laboratory, Dunegan began a study of the life cycle of the bacterial spot organism under Georgia conditions. Roberts and Dunegan also summarized the results of their studies on the life cycle and taxonomy of the peach brown rot fungus in the United States.

Another problem which was studied at the Fort Valley laboratory was the prevalence of the rust fungus, *Tranzschelia pruni-spinosae*, on peach foliage and its relation to a rust which was equally prevalent on wild plum and wild cherry trees.

During this period B. O. Dodge began his comprehensive studies of the rust fungi attacking various species of Rubus and showed that there were long-cycle and short-cycle forms. He found an intermediate form which he believed represented a new species being evolved from a long-cycle form. Dodge's papers were replete with cytological details and many comments upon the evolution of the fungi.

In addition to these investigations Dodge studied the systemic infection of *Rubus* plants and suggested control measures based on his findings. Working in cooperation with F. A. Wolf in North Carolina he also demonstrated that anthracnose (*Elsinoë veneta*) of dewberries could be controlled by spraying the vines with bordeaux mixture.

Dodge also demonstrated that a blight of raspberries was due to a fungus that could not be distinguished from the fungus causing bitter rot of apples. This disease described by Dodge was distinct from the common anthracnose (*Elsinoë*) disease of raspberries which Shear stated was caused by a fungus closely related to, but distinct from the fungus causing the "bird's eye" rot of grapes.

Shear and H. F. Bain described the perfect stage of the fungus causing the stem-end rot of cranberries. This fungus, *Godronia cassandrae*, was first described by Shear in 1917 as *Fusicoccum putrefaciens*.

Other work during this period included the description by Angie M. Beckwith of the life cycle of the grape root-rot fungus, *Roesleria hypogaea*; the suggestion by R. B. Wilcox that the eastern blue-stem disease of black raspberry was a virus disease; the studies by H. F. Bergman on the respiratory activities of various parts of the cranberry plants as well as the oxygen content of bog water; the description of leather rot of strawberries due to *Phytophthora cactorum* by D. H. Rose; and the description by Dodge and Stevens of the *Rhizoctonia* brown rot of strawberries, the *Botrytis* gray mold, and the tan rot due to *Pezizella lythri*.

In 1928 a reorganization program in the Department of Agriculture led to the fusion of the horticultural and pathological staffs. The Office of Fruit Disease Investigations became a part of the new Office of Horticultural Crops and Diseases under the leadership of E. C. Auchter.

THE DECADE 1930-1940

During this period further reorganization in the Department of Agriculture led to the formation in 1932 of the Division of Horticultural Crops and Diseases. E. C. Auchter was the first leader of this new Division and when he was assigned to other duties, H. P. Gould assumed this responsibility in 1938.

The problem of spray injury from liquid lime-sulfur and bordeaux mixture, which had been noted from time to time in the accounts of the previous decades, became increasingly important with the education of the public to demand high-quality fruit, and at the very beginning of this decade a new project was organized for the purpose of devising other fungicides which would give control equal to that obtained with the standard liquid lime-sulfur and bordeaux mixture, but would be less injurious to the host plants. M. C. Goldsworthy and E. L. Green joined the staff in 1930 and started studies of fungicides on a combined chemical and pathological basis. They produced a series of copper compounds, such as copper silicate, copper oxide silicate, copper phosphate, and also began to investigate the possibility of the use of dithiocarbamates as fungicides. They also developed a screening procedure which combined a laboratory test of the toxicity of the fungicide to the spores of certain fungi, a study of the effect upon the material of exposure to outdoor conditions for periods varying from one day to two weeks, and a test of the phytotoxicity of the material on peach and apple leaves.

Materials which proved promising in the screening tests were then subjected to small-scale spray experiments, and if the results continued promising, the following year fairly large-scale, field-spraying tests were started at Vincennes, Indiana, and in the vicinity of Fayetteville, Arkansas, as well as in the orchards of the Plant Industry Station at Beltsville.

During this decade much of the work in the field-spraying experiments was devoted to the investigation of new compounds. While none were found that were completely satisfactory as substitutes for either liquid lime-sulfur or bordeaux mixture, the negative results which were obtained were valuable in that they eliminated from further testing a great variety of inorganic compounds and cleared the field for intensive study of organic materials during the next decade.

During this period M. A. Smith, H. B. Johnson, and Dunegan observed an outbreak of a bacterial disease on English Morello cherries at Seymour, Missouri, and through cross-inoculation experiments were able to prove that the organism was identical with the one producing the bacterial spot disease of peach and plum.

Additional field-spraying experiments were instituted in cooperation with the Missouri Agricultural Experiment Station at the Fruit Experiment Station at Mountain Grove, Missouri, and for a number of years materials were simultaneously tested at Vincennes, Indiana; Fayetteville, Arkansas; and Mountain Grove, Missouri. As a part of this work Goldsworthy at Beltsville, and M. A. Smith at Mountain Grove, Missouri, carried on a study of the life cycle of the pear leaf spot organism, Fabraea maculata, and demonstrated that copper phosphate was an excellent material for the control of this organism and caused no injury to either the pear fruit or the foliage.

Shortly after his transfer in 1928 to Fayetteville, Arkansas, Dunegan found that the peach rust fungus, which had aroused his interest at Fort Valley, Georgia, was present in the Arkansas orchards and caused a premature defoliation similar to that which occurred in Georgia. It was also noted that the aecial stage on Anemone carolinana was extremely prevalent in northwest Arkansas and yet rust did not appear on wild plum and cherry or the peach until the end of the growing season. Inoculation experiments with aeciospores demonstrated that the cherry and wild plum leaves could readily be infected early in the spring but the aeciospores from Anemone carolinana would not infect peach leaves. It was found, also, that aeciospores on Anemone coronaria, an introduced species, would infect such cultivated species as plum and peach but would not attack wild cherry or wild plum leaves.

A series of cross-inoculation experiments and a study of herbarium specimens from all parts of the world demonstrated that these differences in aecial hosts could be correlated with differences in the morphological structure of the teliospores. It was concluded, therefore, that there were two distinct forms of the rust present not only in the United States but throughout the world; attacking on one hand, cultivated forms; and on the other, wild species of the genus Prunus.

Another problem studied at Fayetteville was the obscure disease known as apple measles originally described from northwest Arkansas orchards by J. L. Hewitt and H. E. Truax in 1912. A comparison of current specimens collected in northwest Arkansas with photographs and microscopic slides of the original material led to the conclusion that the disease Hewitt and Truax called "measles" was merely the symptoms produced by the deposition of leafhopper eggs in apple twigs. D. Isley, of the Department of Entomology of the University of Arkansas, assisted in this work. This discovery did not solve the apple-measles problem because other workers subsequent to Hewitt and Truax had included under the term "measles" a variety of obscure bark conditions which were not correlated with leafhopper egg-laying activities. The work in northwest Arkansas, however, made it clear that one form of injury, the only one to which, strictly speaking, the name "apple measles" should be applied, is caused by the deposition of the leafhopper eggs.

A stem-canker disease of peach seedlings in the nursery rows was studied in Arkansas and Missouri, and Dunegan reported that the disease was caused by Phytophthora cactorum.

In the Northwest E. V. Miller in 1932 and J. R. Kienholz in 1939 reported on their studies of the fungi causing apple anthracnose and perennial canker, two diseases caused by closely related fungi. Kienholz found that copper fungicides were effective in the control of anthracnose (Neofabraea malicorticis) in the orchards but did not materially affect perennial canker (N. perennans) infections.

Kienholz also reported in 1939 the result of his studies on stony pit, an obscure disease prevalent on the Bosc and, to a lesser extent, on the Anjou, and other pear varieties in Oregon, Washington, and California. By means of budding experiments Kienholz proved that stony pit is a virus disease. Kienholz, working with Leroy Childs of the Oregon Agricultural Experiment Station, found that the pear scab (Venturia pyrina) organism overwintered on the twigs in Oregon. In seasons favorable to the development of the fungus these twig lesions greatly complicated the control problem.

Hutchins published in 1933 an extensive account of his studies on the phony disease of the peach and stated that the disease is caused by a virus which has an unusually long period of incubation (frequently two full season's growth). The virus, he found, could be readily transmitted by root grafting. In 1937 Hutchins, E. W. Bodine, and H. H. Thornberry described peach mosaic, a new virus disease of peach trees analogous to peach yellows in its contagious nature, rapidity of spread, and menace to the commercial peach industry.

Work of the Division on small fruits was not neglected during this period and in 1931 Stevens reported that since false blossom of cranberries had been found to be transmitted by leafhoppers, he considered one of the factors in the spread of this virus disease to be the replacement of native vines with susceptible varieties. In 1932 Stevens and P. V. Mook reported that strawberry dwarf was due to nematode infections (Aphelenchoides).

R. B. Wilcox and Angie M. Beckwith the following year, in studying the varietal resistance of cranberries to false blossom, found that in comparing varieties the cuttings must be of equal vigor and state of maturity if the comparison between varieties is to be valid.

E. A. Siegler carried on an extensive series of experiments in the control of crown gall (Agrobacterium tumefaciens) on apple nursery stock and reported, among other findings, that the addition of lime to the soil seemed to favor the development of the crown gall organism.

Shear, Stevens, and Bain published in 1931, as a revision of an earlier bulletin by Shear, a monograph on the diseases of cranberries in the United States.

Nellie A. Brown described galls on blueberry stems produced by a species of Phomopsis, while Marguerite S. Wilcox described in 1939 a twig blight of blueberries due to a species of Phomopsis distinct from the one described by Nellie A. Brown, and in 1940 found the perfect stage (a species of Diaporthe) of the blueberry twig blight organism.

J. B. Demaree,. I. Dix, and C. A. Magoon reported in 1937 the results of their studies on the resistance of 270 varieties of grapes to black rot (Guignardia bidwellii) and downy mildew (Plasmopora viticola). They found that 27 varieties were resistant to both fungi, 17 varieties were resistant to downy mildew but susceptible to black rot, and 63 were resistant to black rot but susceptible to downy mildew. Elmer Snyder, working in California, reported that most grape root stocks were susceptible to nematode attacks but a few varieties and their hybrids showed enough resistance to be worthy of further testing.

THE DECADE 1940-1950

H. P. Gould retired in 1941 and J. R. Magness assumed leadership of the Division of Fruit and Vegetable Crops and Diseases on October 1, 1941. Under his inspiring guidance the horticultural and pathological investigations have been further integrated and a closely knit unit working on all phases of fruit and vegetable problems has resulted.

In the field of disease control by spraying, much of the work from 1940 to the present time has been concerned with the development and testing of organic fungicide materials. One of the first materials to be used extensively was ferbam, or ferric dimethyldithiocarbamate, which was used extensively not only by members of the Department of Agriculture but by the various State agricultural experiment station workers. It soon became evident that ferbam was a promising compound since it was fungicidally active and yet produced practically no injury to the leaves and fruit of the apple. In seasons when the environmental conditions were not extremely favorable to the development of the scab fungus ferbam was found to be a satisfactory substitute for lime-sulfur. Experiments, started in Arkansas and subsequently repeated in Delaware, demonstrated that ferbam could be used very satisfactorily as a substitute for bordeaux mixture for the control of the apple blotch fungus; and at the same time, experiments in Arkansas and elsewhere had demonstrated that ferbam was an effective material to use for the control of the apple bitter rot fungus. Since no russetting of the fruit and no serious foliage damage accompanied the use of ferbam, it appeared that one of the objectives for which fruit pathologists had been striving for many years was at last attained; namely, a material that would replace copper and reduce, or practically eliminate, the damage caused by copper fungicides.

Ferbam likewise proved to be effective for the control of pear scab in the Pacific Northwest, and Kienholz in Oregon demonstrated that this compound would control scab and not russet the high-quality pears which were grown in that area.

The introduction of ferbam was soon followed by the introduction by competing firms of other organic chemicals. One of these materials, Phygon (2, 3-dichloro 1, 4-naphthoquinone), proved to be exceptionally effective against the bitter rot fungus in experiments carried on in Arkansas, but it produced a peculiar type of epidermal spotting of the fruit and an irritation of the skin of some workers who used it as a spray or dust.

Goldsworthy and Green studied a series of the dithiocarbamate compounds and concluded that the dimethyl derivatives appeared to possess the greatest fungicidal value, and that among the metallic salts that could be combined with the organic radical, the iron, lead, and zinc salts were the most promising.

The development of organic fungicides was greatly accelerated during World War II by the shortage of copper and other chemicals resulting from the needs of the armed forces. Accompanying this shortage in materials there was also a shortage of human labor and many orchardists turned to mechanical methods of spraying trees, using booms and multiple-outlet units in order to attain, with the limited manpower, the same protection they formerly had obtained with the older methods of spraying.

The advent of the mechanical sprayer, reducing to a matter of a few days the spraying of extensive orchards, made it feasible to reconsider the problem of peach blossom blight control, since it had been found in the 1920 era that a fungicidal spray applied during the blossom period would give protection for about three days. During 1946-47-48, Goldsworthy, R. A. Wilson, and Dunegan tested the feasibility of applying sprays to peach trees at 3-day intervals during the bloom period and found that blossom blight could be materially reduced by three or four such blossom applications. The reduction in the amount of blossom blight was accompanied by a reduction of fruit rot at harvest time. This demonstration of blossom blight control and its relation to fruit rot represents the attainment of another goal which had been in the minds of Department workers for many years.

The problem of bacterial spot control continued to be one of the most serious of all the fruit disease problems. With the advent of organic materials, steps were taken immediately to determine whether or not any of these new preparations would be more efficient than zinc-lime for the control of this most troublesome disease. In cooperation with R. H. Daines, of the New Jersey Agricultural Experiment Station, a variety of materials have been tested in New Jersey peach orchards. Among these were Phygon, copper 8-quinolinolate, zinc-dimethyl dithiocarbamate, chlorine compounds, a variety of inorganic zinc salts, and also, during 1949, N-trichloromethyl thiotetrahydropthalimide, commonly called Orthocide 406. The results with the last named compound were promising in one series of experiments in New Jersey, but they could not be duplicated in the other series and further tests are in progress during the 1950 season. None of the other compounds were as effective as the zinc-lime spray. The control of this peach disease continues to be one of the unsolved problems.

In the Pacific Northwest a variety of organic materials and an antibiotic were tested for the control of the apple mildew fungus. The results with these new materials have not been outstanding. Apple mildew can be controlled, as was found out many years earlier, by the use of liquid lime-sulfur; but this material is open to serious objections and a new fungicide is definitely needed to solve this problem.

Not only was the production of organic fungicides accelerated by the war, but organic insecticides likewise were produced in everincreasing numbers after the introduction of DDT. These organic insecticides have been accepted by growers, but one of the important questions is whether or not these materials will have any residual effect in the soil since large quantities of insecticides sprayed on the trees eventually are deposited upon or mixed with the upper layers of the soil. Experiments on the effect of the accumulation of organic insecticides in the soil on the growth of peach trees and strawberry plants have been underway since 1945. The results obtained at the present time indicate that DDT remains as such in the soil for many years and that it has a very depressing effect upon root formation in the upper few inches of the soil.

The experiments on residual effects of other organic insecticides have not been in progress for a sufficient number of years to warrant any very definite statements. The recently introduced organic phosphate, Parathion, appears to volatilize rapidly and leave no objectionable residue in the soil.

Still another approach, current during the present decade, has been an attempt to improve the control of the apple scab fungus by the combined use of ground spray, originally developed by Keitt and his coworkers at the University of Wisconsin, followed by two applications of an organic mercury spray. This program has been used experimentally for four years by Department workers and the results have been very promising. One limitation to the procedure is the possibility that ascospores from nontreated areas may be carried by the wind into treated orchards.

M. A. Smith studied the obscure bacterial disease of apples called blister spot at the Mountain Grove Experiment Station in Missouri. This had originally been reported to be due to a specific organism, but Smith's laboratory studies indicated it was merely a strain of Phytomonas syringae (= Pseudomonas syringae), a widely distributed greenish-white bacterial organism common on a variety of host plants.

The pathological work on small fruits likewise continued to expand. In 1940, Bergman, who had made preliminary investigations on the oxygen content of water in cranberry bogs, continued to investigate this phase of the problem and noted that ice and snow resulted in an oxygen deficiency for the plants in bogs flooded during the winter. This oxygen deficiency during the winter seriously affected the growth of the plants the following spring. At the same time Bergman and R. B. Wilcox tested ferbam and in 1945 they reported that this new organic fungicide was superior to bordeaux mixture for the control of cranberry fruit rots. They found that spray applied during the blossom period materially reduced the incidence of rot on the fruit at harvest time and during the storage period.

In 1942, Demaree and Marguerite S. Wilcox described a new blueberry canker due to Physalospora corticis and reported that spraying with either bordeaux mixture or liquid lime-sulfur gave inadequate control of this disease. In the same year R. B. Wilcox described a new virus disease of blueberries in New Jersey named "stunt" and four years later Demaree reported that "stunt" occurred in blueberry plants in North Carolina, Massachusetts, and Michigan as well as New Jersey. He found that the disease was spreading rapidly in North Carolina and New Jersey but only slowly in the other two Sttaes. In 1947, Demaree and Marguerite S. Wilcox published an account of the species of fungi, several of which were previously unknown, attacking blueberries, especially those grown in the South Atlantic and Gulf States.

In the strawberry project Bain and Demaree described in 1945 the red stele root rot caused by Phytophthora fragariae, which they found to be widely distributed in the United States. The same disease occurs in England and Scotland where it is called the "Lanarkshire" disease; English workers had described and named the causal fungus. Demaree also described, the same year, a bud rot of strawberry plants due to a species of Rhizoctonia which he found in Maryland and in the southern strawberry-producing sections. The fungus kills the flower and leaf buds during the first few weeks after new growth is resumed.

In 1948, Demaree announced that strawberry yellows, or xanthosis, had been discovered in the eastern strawberry sections. This virus disease had originally been described on western varieties of strawberries not suitable for growing east of the Rocky Mountains, and the eastern varieties do not show the conspicuous yellow-edge leaf symptom so characteristic of the disease in the West. As a control measure, Demaree suggested that all desirable varieties of plants be indexed and virus-free stock be propagated in a vector-free area. He recognized that the maintenance of a virus-free stock will require constant effort.

In 1943, Demaree and Marguerite S. Wilcox described a fungus producing a leaf spot of raspberries. They found similar fungi affecting blackberry and dewberry plants but the fungus from each host was morphologically and physiologically distinct.

In 1946, J. S. Cooley summarized his studies on root diseases of fruit trees. During the 12 years he studied this obscure problem he encountered Phytophthora cactorum, Sclerotium rolfsii, and Corticium galactinum, as well as other commonly recognized root-destroying fungi.

This account of the disease investigations would not be complete without mentioning the project on virus diseases of stone fruit directed by L. C. Cochran in Riverside, California, assisted by E. L. Reeves, H. C. Kirkpatrick, G. E. KenKnight, and B. N. Wadley. This group, working in close cooperation with State workers, have discovered or assisted in the identification of a large number of new virus diseases on stone fruits. Mottle leaf of cherry, Western-X disease, and little cherry have been among their main problems. So extensive have been their activities and so complex is the subject of cross inoculations, virus interrelations, and virus strains, that only a separate report could do justice to their investigations.

DIVISION OF FRUIT AND VEGETABLE CROPS AND DISEASES, BUREAU OF PLANT INDUSTRY, SOILS, AND AGRICULTURAL ENGINEERING, BELTSVILLE, MARYLAND

UNITED STATES DEPARTMENT OF AGRICULTURE RESEARCH ON DISEASES OF CITRUS AND OTHER SUBTROPICAL FRUITS, 1886-1950

Harry R. Fulton

As early as 1886 F. Lamson-Scribner described citrus scab from Florida material, called the disease orange-leaf scab, attributed it to a particular fungus, which he designated as *Cladosporium* sp., and suggested spraying with fungicides for its control. One of the fungicides suggested was "liquid grison", to be prepared by prolonged boiling of sulfur and lime, with subsequent dilution of the clear liquid, essentially a polysulfide preparation equivalent to lime sulfur solution, which later has been largely used for citrus scab control. He does not give results of actual use of this material. In 1891 L. M. Underwood, as special agent, was sent to Florida to make a preliminary study of citrus diseases for the Division of Vegetable Physiology and Pathology. His notes include accounts of die-back, foot rot, blight, scab, leaf spot (*Colletotrichum*), sooty mold, and leaf glaze (*Strigula*). Later in the same year Erwin F. Smith and W. T. Swingle went to carry on further studies, especially on blight. Swingle returned the following spring to continue the work. A field laboratory was established at Eustis, Florida, and H. J. Webber became associated with Swingle in the fall. This was probably the first scientific laboratory to be established for the express purpose of studying citrus diseases. The results of three years of intensive field and laboratory study by these investigators were presented in a bulletin entitled "The Principal Diseases of Citrous Fruits in Florida". The work is notable for the thoroughness with which it was done, and for the emphasis on experimental testing of control measures, many of which are still in successful use. Melanose was added to the list of major citrus diseases, and control was obtained with copper fungicides properly timed. In a somewhat later bulletin Webber summarized investigations on sooty mold and its treatment through spraying to control honeydew-excreting insects, especially the white fly. He pointed out for the first time the entomogenous nature of several species of *Aschersonia*. The destructive freezes of 1894 and 1895 led to suspension of the disease investigations by Swingle and Webber at Eustis.

From 1901 to 1906 P. H. Rolfs at the Bureau of Plant Industry Field Laboratory at Miami investigated anthracnose of lime and other citrus fruits as well as of mango and avocado. He was succeeded by Ernst A. Bessey, whose work for two years included investigations of citrus blight, anthracnose of various subtropical fruits, and nematode host range and distribution.

In 1912 J. G. Grossenbacher began studies on citrus diseases in the Division of Fruit Disease Investigations, with Florida headquarters at Plymouth. His work was broadly planned to obtain information about some of the more baffling bark and wood diseases.

The appearance of citrus canker and the determination of its pathogen (*Pseudomonas* (*Xanthomonas*) *citri*) by Clara H. Hasse ushered in an expanded program for all citrus disease investigations, and H. R. Fulton was placed in charge (until 1935). The field laboratory was moved to Orlando and a special isolated greenhouse for canker studies was built on the Dairy Husbandry Farm at Beltsville, Maryland. The work on established diseases in Florida was under the successive leadership of J. R. Winston, F. A. Wolf, and H. E. Stevens, with the assistance at various times of J. J. Bowman, W. J. Bach, and J. F. Wootten. The research was aimed primarily at solving the growers' problems, and at obtaining a thorough knowledge of the behavior of the pathogens and of the reactions of the hosts. Nutritional disorders were also investigated.

Swingle and Webber had proved that scab and melanose could be controlled with Bordeaux mixture, but its use was followed by increase in scale insects, commonly presumed to be because of reduction of entomogenous fungi, and growers were certainly justified in a reluctance to use it. The Orlando staff found lime-sulfur solution to be satisfactory for light and moderate infections of scab, but it was not sufficiently effective under severe conditions, and it did not give satisfactory control of melanose. More effective control of scab was obtained with a "clean-up" application of bordeaux mixture to cover hold-over lesions on the old leaves, before the spring flush of new growth, and the addition of wettable sulfur to diluted lime-sulfur solution for the fruit cover applications gave a highly effective spray program with a lessened risk of insect trouble.

Melanose was easily controlled with a single cover application of bordeaux mixture under ordinary conditions, but other fungicides were not sufficiently effective. The problem here was to modify the bordeaux mixture so as to get away from the consequent scale insect increase. This was partially effected by reducing the strength of the spray, and by adding oil emulsion. A great variety of other copper fungicides were tested, and for a number of years none was found equal to bordeaux mixture in effectiveness against melanose. A rapid method was developed for testing the residue of copper in spray coatings on leaves. Some of the fixed copper materials that left less residue on the leaves proved to be less likely to incude scale increase. At the present time tribasic copper sulfate is the preferred material for melanose control.

Plantings of Mexican type limes on the Keys were suffering from outbreaks of lime wither tip (Gloeosporium limetticolum). Extensive trials failed to give economical control through spraying, because of the irregularity of blooming and consequent frequency of applications necessary to protect the developing fruit. It was shown that the disease could be greatly reduced by a clean-up application of bordeaux mixture before the new flush appeared, followed by lime-sulfur solution in the bloom and at intervals of a week until the fruits were 3/8 inch in diameter. Pruning, timing of fertilizer applications, and watering practices to induce more regular blooming and fruit setting would be necessary for successful control by spraying; however, these were not practicable under the conditions for growing limes on the Keys.

For all three diseases, scab, melanose, and lime wither tip, the range of host susceptibility, influence of age of tissue, and environmental conditions affecting persistence, spread, and infection were closely studied and the information was used in devising control measures.

Two types of tear-stain surface blemish of citrus fruits occur in Florida and are readily distinguishable, one rough, the other smooth. The rough type is a pattern of melanose injury in the path of trickling water laden with enormous numbers of Phomopsis citri spores. The smooth type of tear-stain was commonly attributed to similar distribution of spores of the omnipresent anthracnose fungus Colletotrichum gloeosporioides. Early in his scab spraying experiments Winston noted that smooth tear-stain was abundant on plots receiving bordeaux mixture, but was absent from those sprayed with lime-sulfur, whereas both fungicides should have been effective against Colletotrichum spores. Furthermore, the well known diffuse type of rust mite injury was present in all plots showing smooth tear-stain but not in the others. The timing of the lime-sulfur applications was right for rust mite control. Additional evidence was obtained from histological comparisons, culturing attempts, and inoculation tests, as well as from extensive field studies of possible association with rust mites or with Colletotrichum and of the effects of spraying practices, all of which led to the conclusion that the smooth, so-called wither tip type of tear-stain in Florida is in reality caused by rust mites and can readily be prevented by controlling the mites.

In cooperation with the Orlando staff, Anna E. Jenkins (1925) worked out the identity of the scab fungus (Sphaceloma fawcetti). A few years later she was sent to Brazil to study a form of scab that had been intercepted on sweet orange fruits, which are practically immune from the common scab of Florida. In 1933 she described this South American sweet orange fruit scab pathogen as Sphaceloma fawcetti var. viscosa. Still later (1936), the perfect stage was found in Brazil, and was described as Elsinoë fawcetti by A. A. Bitancourt and Anna E. Jenkins. During this period Wolf (1926) discovered the perfect stage (Diaporthe citri) of the melanose-producing Phomopsis citri; and N. E. Stevens (1926) found the perfect stage of Diplodia natalensis, the cause of one form of stem end rot, to be Physalospora rhodina. Wolf studied Corticium thread-blight on citrus and other hosts; Winston had previously obtained control of this disease on citrus with one application of bordeaux mixture just before the onset of the summer rainy season.

The discovery of citrus canker in Florida and other Gulf States (1914) brought a crisis to the citrus industry, which was successfully met by a drastic eradication campaign carried on cooperatively with the States involved. K. F. Kellerman, as member of the Federal Horticultural Board and associate chief of the Bureau of Plant Industry had much to do administratively with the success of the undertaking, which is one of the most remarkable achievements in the history of plant-disease control. At the outset, conflict in ideas about the nature of the disease was removed by Clara H. Hasse's determination of its bacterial nature. Her work continued on the physiology of the organism, the relative susceptibility of citrus and other rutaceous hosts, and the effectiveness of bactericides. At the same time Fulton investigated the persistence of the canker organism in the soil and the infectibility of citrus fruits. All of the greenhouse investigations were in close cooperation with the eradication and quarantine work, and were intended to supply needed information.

Since the eradication program made it impossible to carry on control experiments in the citrus-producing regions of the United States, H. Atherton Lee was sent (1916) to the Philippine Islands and to Japan to study field behavior of the disease and methods of control. This seemed important in case eradication proved not to be successful. His work resulted in a series of papers dealing with various phases of the canker problem, as well as with other citrus diseases in the Orient.

An early study of citrus fruit decay was by N. B. Pierce on the Alternaria rot of California navel oranges, in 1901. G. H. Powell's comprehensive study of transportation decay in oranges from California, published in 1908, centered attention on careful handling to avoid invasion by the Penicillium rots. Similar studies with Florida oranges were published in 1914 by A. V. Stubenrauch, H. J. Ramsey, and L. S. Tenny.

Two very serious stem-end rots are prevalent in the Gulf Coast region, caused by Phomopsis citri and Diplodia natalensis. Both become incipiently established in the fruit during its development but decay does not develop until after the fruit is harvested. Early in the work at the Orlando Laboratory it was realized that means must be found for preventing the incipient grove infection or for delaying the development of rot after harvest. The problem was accentuated by the "degreening" treatment in coloring rooms under conditions that promoted development of stem-end rot, especially the Diplodia form. It was early found that the spray treatments for melanose control also reduced the subsequent development of Phomopsis stem-end rot, but only slightly reduced Diplodia rot. Both fungi are harbored in dead limbs and twigs. Pruning out such sources of infection was more effective against Diplodia than against Phomopsis, seemingly because the latter fungus was abundantly present in dead fruit stalks and very small twigs that could not be thoroughly pruned out. Diplodia rot develops most rapidly at temperatures some ten degrees above the optimum for Phomopsis. This explains in part why this form of rot was often more conspicuous in the warmer periods of the shipping season, in the warmer producing districts, and following the degreening treatment in the warm coloring rooms. Both forms of rot are satisfactorily retarded by moderately low temperatures, less cooling being required for Diplodia than for Phomopsis. The stem "buttons" seem to be the part first invaded by the stem-end rot fungi, and it was found that removal of these buttons in the process of degreening effectively prevented stem-end decay. Dipping the harvested fruit in borax solution, first found effective against Penicillium rots, proved to have considerable retarding effect on both forms of stem-end rot, and various forms of borax treatment have been widely used to prevent loss from all of these types of decay.

Notable early studies of tropical fruit diseases were on the bud rot of coconut palms by J. R. Johnston and on the Panama disease or Fusarium wilt of banana by Erwin F. Smith, who described and named the causal fungus.

A disease of Florida pineapples, known as "red wilt", was found by Winston to be a complex in which soil depletion and nematode attack played a part. Control was obtained by rotation with soil-improving cover crops that were resistant to the root knot nematode.

Spraying for control of mango anthracnose, especially the bloom blight phase which prevents fruit setting, was carried on by S. M. McMurran, and later by H. E. Stevens, with reference also to protecting the fruit from blemish and decay. Stevens and R. B. Piper developed successful spraying programs for protection of avocado fruit and foliage from scab, Cercospora leaf spot, and anthracnose. Stevens also investigated sun blotch, a virus disease of avocado, as well as psorosis of citrus, also a virus, and various papaya diseases.

On the retirement of H. E. Stevens in 1945, J. F. L. Childs became leader in the disease work at the Orlando field laboratory. His discovery, in collaboration with E. A. Siegler, that thiourea and certain other fungistats could penetrate citrus fruit tissues and thus control stem-end decay led to expanded efforts along this line. Following this work screening tests with some 1500 compounds have been made at the Orlando laboratory by the fruit-handling staff. Childs' tests of 8 organic fungicides for control of melanose of citrus showed that none of them gave promise of replacing the copper sprays already in use. Work is in progress on testing a large number of citrus rootstock varieties for resistance to foot-rot Phytophthora; on a new disease, presumably virus, on Orlando (Lake) tangelo, to which the name cachexia is given; on the nature of citrus gummosis diseases in Florida; and on the cause of an obscure type of tree decline in that State.

The uneasiness caused by the rapid spread and destructiveness of the tristeza disease of citrus in South America led to the sending in 1946 of C. W. Bennett to Brazil to conduct investigations in cooperation with the Instituto Agronomico do Estados de São Paulo, at Campinas. His work in cooperation with A. S. Costa confirmed the finding of others that the tristeza disease is caused by a virus, transmissible by budding, and that it is spread naturally by the black citrus aphid, Aphis citricidus. Varietal susceptibllity was studied, and the effectiveness of various control measures, none of which seemed satisfactory for general use. Sweet orange, rough lemon, Rangpur lime, and sweet lime as rootstocks seemed to give stock-scion combinations satisfactorily resistant to injury.

Bennett was succeeded in 1947 by Theodore J. Grant. The reactions are being studied of a large number of citrus varieties as rootstocks for sweet orange and grapefruit, and as scions over sour orange and other rootstocks, when inoculated with tristeza virus. Altogether 345 stock-scion combinations are under test, the most promising ones being transplanted in orchard formation for further observation. Tristeza -tolerant rootstocks include various types of sweet orange and mandarin; some lemon and tangelo varieties; and certain other hybrids are promising. None of the 15 varieties of sour orange have proved to be satisfactory. A difference in severity of tristeza was found to be transmissible and is regarded as being due to distinct strains of the virus.

As a precaution against possible outbreak of tristeza in this country, extensive tests are being made of the disease resistance, hardiness, and general suitability of a wide range of citrus types and varieties for use as rootstocks in Florida and in Texas (cooperative work led by W. C. Cooper), especially for use in districts where susceptible sour orange is now in general use in commercial plantings.

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DIVISION OF FRUIT AND VEGETABLE CROPS AND DISEASES, BUREAU OF PLANT INDUSTRY, SOILS, AND AGRICULTURAL ENGINEERING

INVESTIGATIONS OF NUT DISEASES

John R. Cole and Paul W. Miller

PECAN DISEASES

In the early stages of pecan orcharding scab (Cladosporium effusum) was present in destructive amounts on only a few of the improved varieties. Pioneer work on control by spraying was conducted by M. B. Waite at Orangeburg, South Carolina, in 1909, and at Baconton, Georgia, in 1911. The spray equipment of that period was inadequate for use on large pecan trees, and many growers preferred to shift to the more resistant pecan varieties. From 1912 to 1918 thousands of trees of the most susceptible varieties in the humid Gulf Coast area were top-worked to the more resistant varieties. This relief was shortlived, for the scab fungus gradually became destructive on the previously resistant varieties. Furthermore, new introductions regarded as resistant began to show partial to total crop losses from scab soon after they had become extensively planted. The one outstanding exception is the Stuart variety, on which scab does not seem to be increasing in severity. Orchard observations by J. B. Demaree and J. R. Cole suggested the existence of physiologically specialized strains of the pathogen. Experiments showed that when conidia from various sources were applied to several varieties known to be susceptible the heaviest infection resulted when the inoculation was made on the same variety as that from which the conidia were taken.

Since 1918 extensive spraying experiments for scab control have been carried on, in which a wide range of fungicides and improved means of application have been thoroughly tested; and recommendations have been made for economical control by a combination of cultivation to bury hold-over husks and leaves, pruning to give more open tops, and proper timing of 4 or possibly 5 spray applications to protect leaves and nuts during their period of susceptibility, which extends well through the summer in the case of the nuts. Spraying equipment must be capable of effective work on trees 40 to 60 feet in height, or even taller. Home-made bordeaux mixture with low lime content still holds its place at the top in effectiveness. Recently ziram is giving good scab control, with more healthy, greener foliage and less severe black aphid infestation than have followed use of bordeaux mixture. However, ziram is "specific" in the case of certain varieties, e.g., Moore and Schley, but is less effective on others, such as Moneymaker.

Pecan scab control investigations are being continued, including the new types of fungicides and methods of application, especially mist sprayers applying concentrated materials, which may prove to be especially advantageous in pecan orchards.

Several fungi attack pecan leaves, causing functional decline and premature defoliation, with consequent reduction in nut quality and yield. These fungi do not destroy the nuts, and they are readily controlled by orchard sanitation and spraying. Studies on the morphology, physiology, pathogenicity, and control of leaf blotch (Mycosphaerella dendroides) and downy spot (Mycosphaerella caryigena) have been reported by Demaree and Cole, and of vein spot (Leptothyrium nervisedum) and liver spot (Gnomonia caryae var. pecanae) by Cole, all published in the Journal of Agricultural Research, 1930-33.

A disease of pecans, known as "bunch", is characterized by a witches'-broom type of growth. It is found west of the Mississippi River on the native pecan and water hickory, and in many planted orchards. The Schley and Mahan varieties are the most susceptible, while the Stuart is the most resistant. Bunch is infectious, but no parasite has been identified, therefore it is probably a virus disease.

Pecan rosette was investigated by W. A. Orton and F. V. Rand, who reported in 1914 that no parasitic organism was associated with the disease and concluded that the cause of the trouble was in the soil; it was thought that "the direct cause will ultimately be found in some lack of balance in the nutrient supply." S. M. McMurran worked on the problem from 1914 to 1920. He found that rosette was usually associated with soil unsuitable for thrifty growth, either of pecan trees or of weeds and crops generally. He indicated deficiency of humus, of plant-food material, or of moisture, or a combination of these, as being factors. In 1919 Waite reported: "Extensive field experiments on pecan rosette have shown this disease to be physiological and due to soil conditions. Stable manure has been demonstrated to be an effective, though not always practical, remedy for these conditions."

J. J. Skinner and Demaree (10), in their experimental work with rosette in southern Georgia, were able to bring badly rosetted trees that were growing on soils low in organic matter back to normal by growing and turning under two green manure crops each year. Chemical fertilizers, as used in the experiment, had no influence in increasing or decreasing rosette.

In 1931 A. O. Alben, J. R. Cole, and R. D. Lewis (1), while conducting experiments to control rosette, concluded that "pecan rosette is apparently a nonparasitic disease of widespread distribution occurring on both residual and alluvial soils. The writers were able to improve old rosetted leaves and bring the young ones back to normal by dipping or spraying them with a solution of ferric sulfate or ferric chloride, ranging in strength from 0.6 to 1 percent. These findings would seem to indicate that pecan rosette is a condition of iron chlorosis."

In 1932 these investigators further discovered that "with the enlargement of these experiments undertaken at the beginning of the 1932 season, more or less conflicting results began to appear. The experiments included injection of iron salts into dormant trees; application of iron salts to the soil around the trees, while they were still dormant; after the foliage was well developed, spraying by various procedures with both ferric and ferrous sulfate; and dipping terminal branches that showed the rosette symptoms in solutions of iron salts. The only favorable results were associated with the small-scale experiments where galvanized iron containers were used in handling the solutions. It was further found that the iron salts used contained appreciable quantities of zinc. Accordingly, a small series of experiments were undertaken, using shellaced crocks instead of galvanized buckets. The effects of zinc sulfate and zinc chloride solutions were compared with the effect resulting from iron sulfate solution. One immersion in the iron solution failed visibly to improve conditions, while zinc sulfate and zinc chloride solutions restored the new leaves back to normal condition. These results were secured with trees located on both alkaline and acid soils.

"Our experiments in spraying foliage with zinc sulfate or zinc-lime sprays and also the experiments in dipping terminal parts of branches showing pronounced rosette symptoms in zinc solutions and the prompt and favorable response of the trees to such treatments apparently indicate that zinc is an essential element for the healthy development of the pecan tree."

The investigations of Alben, Cole, and Lewis in the western part of the pecan belt, where soils are mostly alkaline, were supplemented by extensive experiments conducted by J. B. Demaree, H. L. Crane, and E. D. Fowler on acid soils of the Southeast. In this way the problem of zinc deficiency control was quickly solved and growers were enabled to overcome the disease throughout the area of commercial production. Control is readily obtained by spraying with a solution of zinc sulfate or by broadcasting the chemical; but the latter method is effective only under acid soil conditions. The solving of this important problem has materially aided growers in their pecan production program.

WALNUT DISEASES

An early reference to walnut bacteriosis, or blight, occurs in the 1893 report of the Chief of the Division of Vegetable Pathology of the U. S. Department of Agriculture. In 1896 and during the next five years N. B. Pierce published accounts of it as found on Persian walnut in California, with discussion of the life history of the causal organism and reports on limited attempts to control the disease. In 1901 he published a technical description of the causal bacterium, giving it the name Pseudomonas juglandis. In the Eastern States the disease was later studied by S. M. McMurran, who published his findings in 1911. B. A. Rudolph of the California Agricultural Experiment Station, in 1928, obtained successful control by spraying in the growing season, rather than in the winter dormant period.

In 1930, Paul W. Miller began work on the problem under Pacific Northwest conditions in cooperation with the Oregon Experiment Station. Attempts to control by Rudolph's program gave variable results under conditions there. Miller made a complete study of the epidemiology of the disease and applied the information to the problem of effective control. Several satisfactory spray and dust formulas were worked out, and the proper timing of applications determined. In collaboration with W. B. Bollen of the Oregon station, a comprehensive technical bulletin was prepared covering the physiology of the causal organism, its life history in relation to pathogenesis, and the development of control measures.

Investigations are in progress to test efficiency of new organic materials, and of concentrated sprays applied with modern high-power mist sprayers. Several other important walnut disorders in Oregon have been studied including non-parasitic "black line", a leaf scorch and twig dieback due to deficiency of boron, crown rot, mushroom root rot, and an undetermined rot of crown and roots.

FILBERT DISEASES

In the cooperative nut disease investigations in Oregon primary consideration is being given to filbert bacteriosis, caused by *Xanthomonas corylina*. Other diseases of importance have received attention; including powdery mildew, crown gall, mushroom root rot, and wood and heart rots caused by a variety of wood-rotting fungi.

The main infection period for filbert bacteriosis was found to extend from the time the winter buds are about three-fourths grown (late summer) until they open the following spring. Cankers on trunks and larger branches are the most important source of primary inoculum. Methods for control were worked out for prevention of extensive establishment of the disease in young trees and for spraying older trees with a protectant bactericide. In normal seasons one spray application made in late summer before the first fall rains gives satisfactory control. A complete report on filbert bacteriosis was published as an Oregon technical bulletin by P. W. Miller, W. B. Bollen, and J. E. Simmons.

Miller and C. E. Schuster investigated the effects of high-lime and low-lime bordeaux mixture on the transpiration rate of Persian walnut and filbert plants. No uniform effects were noted on either walnut or filbert, and there was no marked difference between the two types of bordeaux mixture.

TUNG DISEASES

Thus far tung orchards in the Southeastern States have been remarkably free from destructive outbreaks of infectious diseases. This is especially fortunate since the returns from the crops do not justify expensive control procedures. The tung tree has been rather quick to show effects of nutrient deficiencies in certain types of soil in the tung belt, but these disorders can be readily and economically remedied once they are recognized. The parasitic diseases that have shown up are mostly sporadic and are caused by well-known organisms that are somewhat weakly parasitic on a considerable range of host plants in the tung belt.

J. R. Large investigated a girdling canker disease found in a nursery and on young orchard trees in several localities. He attributed the disease to *Physalospora rhodina*. The perfect stage, as well as the *Diplodia* form, was found associated with the cankers.

Thread blight (*Corticium stevensii*) and web blight (*Corticium microsclerotia*) have been occasionally encountered. Experiments have shown that control of thread blight by pruning is not practical after the disease has become established in a bearing tung orchard, but that spraying with bordeaux mixture once a year early in June will control it. A nut rot attributed to *Botryosphaeria ribis* causes premature dropping of fruit and reduction in oil content. A few instances of death of trees from *Clitocybe* root rot have been observed. Root knot nematodes have caused stunting of tung trees in the nursery.

Lucia McCulloch and J. B. Demaree isolated a bacterium from tung leaf spots and infected healthy plants by inoculating with the pure cultures. They named the organism *Bacterium aleuritidis*.

Demaree and Large studied a type of tung leaf variegation which seemed to involve an inheritance factor rather than the presence of virus.

Large investigated a disease that caused rough bark and willowy twisted branches of tung; he transmitted it by budding, which indicates, in the absence of any causal organism, that the disorder is a virus infection.

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DIVISION OF FRUIT AND VEGETABLE CROPS AND DISEASES, BUREAU OF PLANT INDUSTRY, SOILS, AND AGRICULTURAL ENGINEERING

DISEASE INVESTIGATIONS WITH ORNAMENTAL CROPS IN THE UNITED STATES DEPARTMENT OF AGRICULTURE

Philip Brierley

INTRODUCTION

Ornamental plants have always had a strong appeal to plant pathologists, as is shown by the research issuing from divisions operating under broad directives. Even before the Department of Agriculture attained cabinet rank in 1889, studies on diseases of ornamentals were included in the Commissioner's Reports. Later a great many contributions of value came from Erwin F. Smith's Laboratory of Plant Pathology. Also, from the Division of Mycology we have a number of substantial papers. The work of the Division of Nematology and of the Division of Forest Pathology is not included here, although these divisions also deal with ornamental plants in part. It was not until 1926 that the Department had a specific directive to study diseases of ornamental plants and a project was organized for this purpose with the Division of Cotton, Truck, and Forage-Crop Disease Investigations. This work is now a part of the Division of Fruit and Vegetable Crops and Diseases. The alarm felt by producers of narcissus over losses incurred from basal rot was largely responsible for the initiation of these studies. At length research did produce a commercial control for this disease, as is pointed out in a later paragraph. In order to keep this discussion within bounds, the many research publications by Department workers on diseases of ornamentals are briefly sketched, followed by one selected accomplishment -- the control of narcissus basal rot --, and a sample current research project -- the control of diseases of gladiolus.

At the outset work on diseases of ornamental plants was quartered in the West Wing of the Department of Agriculture building, with greenhouse space at 12th and Constitution Avenues and later at Arlington Farm. In 1935 this work was moved to Beltsville to the new Horticultural Field Station, now Plant Industry Station, to become a part of a new project on Florists' and Nursery Crops. The disease work was originally staffed by Freeman Weiss and the writer. Lucia McCulloch joined us after E. F. Smith's group was disbanded in 1930; she retired in 1941. In 1941 W. D. McClellan came to Beltsville and in 1942 D. L. Gill began studies on azalea diseases at Baton Rouge, Louisiana, continued later at Spring Hill, Alabama. Other workers served more briefly, Thelma Bennett Post and E. L. Evinger at Beltsville and J. F. L. Childs and Cynthia Westcott at Spring Hill. Cooperative relations have long been maintained with the Oregon Experiment Station at Corvallis, with M. B. McKay and, later, F. P. McWhorter as agents of this Division. Similar cooperation with the New York (Cornell) Experiment Station at Babylon and Farmingdale, Long Island, has been staffed at various times by F. A. Haasis, D. B. Creager, C. E. Williamson, and A. A. Foster as agents or collaborators. Our group has enjoyed excellent cooperation from the Division of Truck Crops and Garden Insects of the Bureau of Entomology and Plant Quarantine. F. S. Blanton of that division worked on vector relations of narcissus viruses with F. A. Haasis, and Floyd F. Smith has made vector studies of a wide range of viruses of ornamental plants in cooperation with the writer. N. W. Stuart, physiologist of our own project, has made a number of contributions on nutritional relations of pathogenic fungi and on deficiency diseases of ornamental crops.

SOME EARLY BEGINNINGS: In the Reports of the Commissioner of Agriculture and, after 1889, of the Secretary of Agriculture are to be found a number of papers on plant diseases, including a few on the diseases of ornamental plants. One of the earliest of these was Thomas Taylor's account in the Commissioner's Report for 1871 of mildew of the lilac "genus *Microsphaeria*", including sketches of the conidial and perithecial stages that are recognizable but unskilled. The quality of these papers improved steadily, but for the most part they continued to be informative reports rather than original studies. In 1887 F. L. Scribner included descriptions of rose blackspot and two rust diseases of rose in his extensive report for the Section of Vegetable Pathology. In 1889 D. G. Fairchild presented a description of the disease of mignonette caused by *Cercospora resedae*. Miss E. A. Southworth, the first lady scientist in this field in Government service, in 1888 distinguished the rose leaf spot caused by *Cercospora rosaecola* from the better known blackspot. In 1890 she revised the description of hollyhock anthracnose and its causal agent *Colletotrichum malvarum*. In 1897 A. F. Woods presented an account of the Bermuda lily disease. His description strongly suggests the virus disease now known as necrotic fleck, but other defects were doubtless confused with this, and a virus cause was not visualized. P. H. Dorsett, in his Spot Disease of the Violet (1900) described an important disease of a crop then extensively cultivated. He erected a new species *Alternaria violae* for the causal agent and proved its pathogenicity.

E. F. SMITH AND THE LABORATORY OF PLANT PATHOLOGY: Erwin F. Smith entered the Department in 1886 to undertake a study of peach yellows. He failed to solve this problem, but attained world prominence in plant bacteriology, and gathered in his Laboratory of Plant Pathology a staff of skilled workers in this special field. Smith's own studies ranged over all classes of crops including a few ornamentals. He described (1896) *Bacillus* (*Pseudomonas*) *solanacearum*, and with his colleague C. O. Townsend (1907) named the crown gall organism *Bacterium* (*Agrobacterium*) *tumefaciens* -- two pathogens of wide host range and of significance to ornamental plants. He assigned the name *Bacterium* (*Pseudomonas*) *woodsii* to the carnation leaf-spot pathogen earlier noted by A. F. Woods, and rechecked in detail the earlier work of Wakker in Holland on hyacinth yellows caused by *Pseudomonas* (*Xanthomonas*) *hyacinthi*. Townsend in 1904 described *Bacillus* (*Erwinia*) *aroideae*, one of the soft rot bacteria attacking calla lillies and other plants. Three of Smith's staff of specialists in bacterial diseases joined the Division of Fruit and Vegetable Crops and Diseases after the Laboratory of Plant Pathology was disbanded following his death in 1927. Nellie A. Brown, Mark K. Bryan, and Lucia McCulloch each contributed significant work on diseases of ornamentals both before and after that change. Miss Brown described *Bacterium* (*Pseudomonas*) *aptatum* causing a leaf spot of nasturtium and beet, and *Bacterium* (*Xanthomonas*) *pelargonii* causing a troublesome leaf spot of the florist's geranium (*Pelargonium* spp.). She also distinguished *Bacterium* (*Agrobacterium*) *gypsophilae*, as the cause of a root gall of *Gypsophila*, and *Phomopsis* sp. as the causal agent of a stem gall of *Viburnum* spp. Both of these gall diseases had been confused with crown gall, with which Miss Brown had worked extensively. Mary K. Bryan described *Bacterium* (*Xanthomonas*) *cannae* causing budrot of canna, and, with F. P. McWhorter, *Bacterium* (*Xanthomonas*) *papavericola*, the cause of blight in poppies. She also made detailed studies of the pathogens of bacterial leaf spot of Delphinium, and of lilac blight, both of which had been described earlier. Lucia McCulloch described the pathogens of gladiolus bacterial blight, *Bacterium* (*Xanthomonas*) *gummisudans*, and of gladiolus scab, *Bacterium* (*Pseudomonas*) *marginatum*, and also the agent of leaf blight of iris, *Bacterium tardicrescens*, and that of a leaf spot of begonia, *Bacterium* (*Xanthomonas*) *flavozonatum*, the last not certainly distinct from the earlier *X. begoniae*. With R. P. White she made a detailed study of the bacterial leaf spot of English ivy and of its causal agent, *Xanthomonas hederae*. Later, with Charles Thom, she described *Penicillium gladioli*, the cause of a corm rot of gladiolus, and studied *Fusarium* corm rot of gladiolus and its control. Other contributions from the Laboratory of Plant Pathology on fungus diseases were F. V. Rand's description of *Helicosporium* (*Helicoceras*) *nymphaearum* and the leaf spot it induces in pond lilies, and Harry Braun's study of geranium stem rot caused by *Pythium complectens*. These papers from the Laboratory of Plant Pathology are scholarly, and have stood the test of time except for nomenclatural changes. They are mainly descriptive contributions. Suggestions for controlling the diseases are usually sanitary measures or are lacking. Indeed, the bacterial diseases are still difficult to control, and perhaps the lack of effective and immediately useful remedies may account for the decline of plant bacteriology from its former position of eminence to near the vanishing point in this Department.

CONTRIBUTIONS FROM THE MYCOLOGISTS: Continuing the work begun by Scribner and Southworth members of the Division of Mycology and other mycological workers have clarified several of the fungus diseases of ornamentals. In 1910 Flora W. Patterson and Vera K. Charles noted *Botrytis paeoniae* causing peony blight, and *B. cinerea* causing ray blight in florists' chrysanthemums. An anthracnose of cyclamen was shown to be caused by a variant of *Glomerella rufomaculans*, which they described as a new variety. Anna E. Jenkins described brown canker of rose, a troublesome disease in eastern and southern United States, since found also in Europe, that had been confused with other canker diseases and with winter injury. The pathogen which she described as *Diaporthe umbrina* is now referred to as *Cryptosporella*, for the ascospores are usually unicellular. Miss Jenkins presented the original descriptions of the disease and of the pathogen, and also studied its seasonal development in detail. She also described *Sphaceloma rosarum*, cause of the nearly worldwide spot anthracnose of roses, which had been misinterpreted and confused with other leaf spot diseases. With N. E. Stevens she showed that the currant cane blight fungus *Botryosphaeria ribis* can cause die-back in roses. With L. M. Massey she described another spot anthracnose, or scab disease, of violets caused by *Sphaceloma violae*. Miss Jenkins also established *Ascochyta majalis*, a fungus previously known only from Europe, as the cause of a leaf spot of lily-of-the-valley. Alma M. Waterman of the Division of Forest Pathology, who was long assigned to the study of rose diseases, presented a comparative study of the *Coniothyrium* cankers of rose -- brand canker caused by *C. wernsdorffiae* and cane canker by *C. fuckelii*.

RESEARCH IN THE ORNAMENTALS PROJECT

BULB DISEASES: Narcissus. Two leading diseases of narcissus are omitted here: Fusarium basal rot is reserved for special treatment below, and the narcissus nematode disease is omitted as being outside the scope of this review. A general account of diseases affecting narcissus offered by McWhorter and Weiss in 1932 includes these diseases and others known at the time. Narcissus bulbs are subject to wet scale rot caused by Sclerotium rolfsii and to two scale speck organisms assigned to Sclerotium spp., as well as to Rhizopus rot after injury. Leaf diseases are smoulder caused by Botrytis narcissicola, leaf scorch due to Stagonospora curtisii, and white mold, Ramularia vallisumbrosae. Creager studied the morphology and life cycle of Stagonospora in detail. Two virus diseases are generally prevalent, reducing bulb yields and impairing flower quality. Mosaic, called yellow stripe in Europe, was first shown to be sap transmissible at the Oregon Station; but Haasis at Babylon, New York, first determined properties of the virus and later F. S. Blanton and Haasis showed that seven species of aphids can serve as vectors. A second virus, causing the disease known as white streak or decline disease, has been shown by Haasis to be sap transmissible and by Blanton to be aphid borne. The cooler climate of the Pacific Northwest is less favorable for development of Fusarium basal rot and also for increase of the aphid vectors of the virus diseases, but is favorable for bulb increase. For these reasons narcissus production is intensified in that area, although leaf diseases of negligible importance in Eastern centers may require additional control measures in the Northwest.

Tulip. Department research on tulip diseases has been largely confined to the virus disease tulip mosaic, or tulip breaking. The striking rearrangement of color in the broken flower is so distinctive that the existence of tulip breaking can be traced far back into history, to 1576, as shown by M. B. McKay and M. F. Warner. Proof that breaking is due to a virus transmissible by sap and by aphids was presented independently by English workers and by McKay, Brierley, and T. P. Dykstra at about the same time. More recently extensive studies on tulip breaking have been reported by McWhorter, and by Brierley and Smith. McWhorter has offered a theory that the light and the dark breaking patterns in tulips are produced by two distinct viruses that are present in balanced proportions in the common broken tulip, which shows a mixture of light and dark areas. Tulips infected at flowering time develop breaking in the following season, but if plants are infected early they may express symptoms in the same season. Cucumber mosaic virus can affect tulip, but this disease is uncommon in tulips in the United States and readily distinguished from tulip break. Some lily mosaic strains can induce breaking in tulips as McWhorter first demonstrated. Control of tulip breaking is more practicable in areas of low aphid prevalence, and roguing to eliminate disease is complicated by weak expression of symptoms in white and yellow tulip varieties.

Lily. Virus diseases, which are of major importance in lily culture, have been studied intensively by Department workers. Close teamwork between Pathology and Entomology bore fruit in the studies of Brierley and Smith on necrotic fleck and on mottle of Easter lilies. The necrotic fleck disease, first introduced into Louisiana, has become generally distributed in the Southeast but is still rare in the Northwest where exclusion has been more rigidly practiced and where aphid vectors are less abundant. This disease of the Easter lily has been shown to be caused by a complex of two viruses. One is the common cucumber mosaic; the other is a virus peculiar to Easter lily and inducing no symptoms when present alone, which Brierley and Smith have designated lily-symptomless virus. This symptomless virus is carried by Aphis gossypii only, and in the persistent manner. It has become general in commercial stocks of Easter lily, presenting no warning of its presence until cucumber-mosaic virus is added. Cucumber-mosaic virus, present in flecked lilies and sporadically in vegetable crops, in certain other ornamentals and wild hosts, may be carried by Myzus persicae and Macrosiphum solanifolii, as well as by Aphis gossypii, in the non-persistent manner in each. Migrant aphids of any of these species, notably M. persicae, may spread the cucumber-mosaic virus at amazing rates as they pass over Easter lily fields, leaving necrotic fleck symptoms to develop later. If aphids are not controlled under glass, similar increase of fleck may take place before the crop is marketed. A third virus, which we have termed lily-mottle virus, is extremely common in commercial stocks of Easter lilies. This virus, a member of the tulip-breaking group, is not recognizably damaging to Easter lilies, but is ruinous to some garden lily species and to tulips. It is transmitted in the non-persistent manner by the three species of aphids mentioned above. None of the lily viruses are known to be seed borne.

Lily-rosette virus, transmitted by Aphis gossypii only, and in the persistent manner, has been shown to be capable of infecting a number of other Lilium species (Smith and Brierley). The rosette disease is difficult to diagnose for symptoms may be imitated by other disorders, such as the feeding injury of Myzus convolvuli. McWhorter and Brierley have developed a technique for diagnosing rosette from the phloem abnormalities induced. Smith and Brierley have shown that lily viruses of both persistent and non-persistent classes may be transmitted during storage of the bulbs if the appropriate vector species is present in the storehouse. A mosaic disease common in *Ornithogalum* and certain other members of the tribe Scilleae of the Liliaceae is distinct from the lily viruses and not transmissible to lilies.

Fusarium rot of lily bulbs, caused by *F. oxysporum* f. *lilii*, is limiting in production of some lily species, and particularly destructive of the bulb scales when these are used in propagation. McClellan and Stuart have tested a number of fungicides, alone and in mixture with hormones, as protectants against this decay of lily scales. Formaldehyde proved injurious to the scales, but Arasan and Fermate provided good protection against rot of the scales both under glass and in the field. No significant advantage was found in the use of these same fungicides on bulb planting stock. Charles Drechsler has identified *Phytophthora cactorum* as the cause of a foot rot in certain garden lily species. A leaf scorch peculiar to the Croft variety of Easter lily has been shown by N. W. Stuart to be a nutritional disorder that may be corrected in part by side dressings of nitrogen fertilizer.

Iris. Diseases of bulbous iris and their control were discussed by McWhorter (1940). Bulb rots caused by *Sclerotium rolfsii* and by *Penicillium* sp. have been studied by Weiss, and the leaf diseases caused by *Mystrosporium adustum* and *Heterosporium iridis* (*Didymellina macrospora*) by McWhorter. Miss McCulloch's work on bacterial leaf spot of iris has been noted above. The mosaic of bulbous iris was originally described by Brierley and McWhorter. This virus is sap transmissible and carried by *Myzus persicae* and by *Macrosiphum solanifolii*. More recently Brierley and F. F. Smith have shown that the common mosaic of bearded iris and a mosaic of beardless iris differ from each other and from bulbous iris mosaic in host relations.

Gladiolus. Problems of disease control in gladiolus have multiplied as this crop has forged ahead in importance among florists' crops. These problems are discussed at the close of this account. Among Department contributions to the subject are Miss McCulloch's accounts of bacterial blight, scab, and *Penicillium* storage rot that have been mentioned above. She also studied the *Fusarium* disease in detail, and suggested soil treatment with chloropicrin as a control measure against the soil-borne phase. W. D. McClellan has outlined the symptoms of the *Fusarium* disease in leaves, corms, and roots, and has also shown that additional Iridaceous plants are susceptible. McClellan and N. W. Stuart have studied nutrient requirements of gladiolus and the effect of fertilizers on incidence of *Fusarium* rot. They find that nitrogen fertilizers increase losses due to *Fusarium*. McClellan, K. F. Baker, and C. J. Gould have pointed out that *Botrytis gladiolorum* is a low-temperature pathogen, causing leaf and flower blight in winter-crop gladiolus in Florida and corm rot where cool moist weather prevails at harvest. Brierley and Smith first showed that the mild mosaic of gladiolus is aphid-borne. McWhorter and L. Boyle showed that this mild mosaic of gladiolus is bean-yellow mosaic. The writer and Smith distinguished the white break disease, which is damaging to individual gladiolus plants but sporadic in occurrence. White break spreads in field plantings but the insect vector is not yet known. The aster-yellows virus was identified in gladiolus by Smith and Brierley.

ROSE DISEASES. The contributions of Miss Jenkins on brown canker and on *Sphaceloma* leaf disease of roses, as well as those of Miss Waterman on the *Coniothyrium* cankers, have been noted above. W. D. McClellan, who was familiar with rose mildew from research conducted before entering the Department, has called attention to the upsurge of this disease in greenhouse roses as syringing has been supplanted by aerosols for control of red spider mite. Brierley and Smith redefined the symptoms of rose mosaic, called attention to yellow mosaic types, differentiated mosaic symptoms from certain crinkle and speckle patterns in understocks not known to be of virus origin, and concluded that rose mosaic is spread in nursery practice rather than by insects in the United States. In the same paper they described rose streak, a necrotic virus disease likewise transmitted by tissue union only. They noted recently that rose mosaic is still present in forced roses but less prominent now because of changes in varieties. G. E. Yerkes, L. B. Scott, and C. F. Swingle determined that immaturity in Manetti understocks was responsible for some rose failures formerly confused with mosaic effects, and devised a starch test for maturity.

AZALEA DISEASES. A petal blight of cultivated azaleas was observed near Charleston, South Carolina, in 1931, and later was found from Texas to Maryland. Freeman Weiss described the pathogen as *Ovulinia azaleae* and worked out its life history and seasonal development. With Floyd Smith, he showed that bees and other insects may contribute to secondary spread of the disease, carrying spores for two miles or more. Early attempts at control by sanitary measures were unsuccessful. Miss Westcott showed Dithane and Phygon to be effective as protectant sprays. The writer found eradicants effective in suppressing apothecia, but practical applications of this have not been made. D. L. Gill has tested a wide range of protectants, confirming the effectiveness of

Dithane D-14 and adding Parzate and Dithane Z-78 as applicable against petal blight. Phygon has been discontinued as too injurious. Dusts are useful but they are less effective than sprays. Three applications of spray or dust per week during the flowering season are needed for good control of the disease.

DISEASES OF OTHER ORNAMENTALS. Camellia yellowspot, a virus disease transmissible by grafting, was described by J. A. Milbrath and F. P. McWhorter. Gill has determined *Phytophthora cinnamomi* as the cause of a wilt and root rot of camellia in nurseries. Brierley and Smith studied canna mosaic, finding the President variety immune. The same writers found carnation mosaic transmissible by *Myzus persicae* as well as by sap, and the Sweet William useful as a test plant for the virus. The streak disease of carnation is not transmissible by sap or by *M. persicae*, but natural spread occurs in outdoor plantings. They also established the cause of chrysanthemum stunt as a virus transmissible by sap and by grafting. Confusion and fear accompanied the appearance of the stunt disease in florists' chrysanthemums, but commercial control followed quickly after this proof of the nature of the disease. Mrs. Post reported a stem rot of dahlia caused by *Macrophomina phaseoli*. Brierley studied the mosaic disease of dahlia, distinguishing this virus disease from various insect injuries lumped with mosaic under the loose term "dahlia stunt". The mosaic virus is transmitted by *Myzus persicae*. Dahlia varieties vary widely in tolerance of mosaic, the more tolerant sorts serving the producer of cut blooms but acting as carriers in general collections. Dahlia ringspots, described by Brierley along with dahlia mosaic, are now recognized as symptoms of tomato spotted wilt. McClellan has shown that applications of chloropicrin or of nitrogen fertilizers, especially ammonium nitrate, afford some control of *Sclerotium rolfsii* causing crown rot of delphinium in Texas.

THE CONTROL OF NARCISSUS BASAL ROT

Before 1924 about 77 million narcissus bulbs were imported annually, chiefly for greenhouse forcing. In anticipation of quarantine restrictions imposed against narcissus nematode and bulb flies, and effective July 15, 1926, increasing numbers of bulbs were imported during 1924, 1925, and 1926, largely for use as planting stock to establish domestic supplies. Such imports reached 142 million bulbs in 1926. Several factors contributed to the rise of narcissus basal rot as a commercial problem at this time. In the first place many growers were unfamiliar with the culture of narcissus, or the Hollanders who undertook production in this country were unfamiliar with the climatic and soil factors encountered. Second, the cultures along the Eastern Seaborad from Long Island to the Carolinas encountered higher soil temperatures at harvest and at planting seasons, also higher temperatures during summer storage and shipment periods, than had been experienced in Holland. Third, the bulk of the stock planted in these early ventures was made up of very susceptible varieties, such as Golden Spur, Victoria, Spring Glory, Empress, and Emperor. Fourth, the hot water treatment, 110° F. for 2 1/2 hours, required for interstate movement if nematodes were found in the stock, proved an effective means of increasing basal rot. And finally, basal rot presented a new problem with little or no information available on cause, conditions of development or control. Basal rot was confused with the damage caused by nematodes and by narcissus flies, or with the *Rhizopus* rot that follows sun scald, or was attributed to overheating effects directly. Research on the disease was conducted simultaneously in England, in Holland, and in the United States, but the results of workers abroad were not available as a guide until the later stages of the problem.

A *Fusarium* was soon established by Weiss as the cause of basal rot. English workers later assigned it the name *Fusarium bulbigenum*, but American workers follow Snyder and Hansen in terming it *F. oxysporum* f. *narcissi*. This basal rot *Fusarium* is highly specific for narcissus, although closely allied forms attack other ornamental and vegetable crops. The trumpet varieties are highly susceptible, other classes, such as the Barrii, Leedsii, and Imcomparabilis, are somewhat less so, and the Polyanthus types are practically immune. However, the Polyanthus types are less hardy and therefore restricted to the warmer parts of the United States, and they meet an entirely different market demand. Trumpet varieties still dominate the cut-flower market, for forcing under glass or for cutting in the open field. It was noted early that trumpet varieties with hard bulbs, such as King Alfred, were less subject to *Fusarium* than the soft bulb sorts; but this difference is not a wide one. Although the extremely susceptible bicolors have nearly disappeared from commercial culture, King Alfred, still a leading commercial variety, has suffered severe inroads of basal rot in the East. A few Barrii varieties grown in North Carolina have proved less subject to *Fsuarium* but find limited market demand.

The development of basal rot is favored by moderately high temperatures, about 70° to 90° F., and is much slower at 60° F. or below. The *Fusarium* is originally introduced into fields in infected bulbs, but it can persist in soil. In regions where high soil temperatures occur before the bulbs are dug, infection may take place from the soil and rot can progress further during storage. Also high temperatures after fall planting permit extension of incipient infections and lead to death of the plants in the field. In cooler regions, such as the Pacific Northwest, the Fusarium is relatively inactive in the soil and becomes a disease of storage and transit. As such facts became known growers changed cultural operations to minimize rot hazards. Such measures include rotation of plantings to avoid infested soil, early harvest of the bulbs, avoiding injuries in handling and overheating from exposure to bright sunlight or from massing moist bulbs in tight containers, quick drying of the bulbs after digging, careful sorting before and after storage, and storing in shallow layers in cool, well-ventilated storehouses. However, market demands call for susceptible trumpet varieties, and the warm soils of the East are conveniently accessible to markets. Hence research early turned to chemical treatment of the bulbs in the hope of checking the disease even where the climate and the varieties favored it.

Contamination of sound bulbs during the hot water treatment for nematode control was confirmed by Weiss, and the addition of formaldehyde or mercurials to the water was shown to prevent this. Inasmuch as hot formaldehyde is more effective against nematodes than hot water alone, an 0.5% formaldehyde bath has become standard. This treatment for nematode control also affords effective control of Fusarium in England, and supplementary fungicidal treatments against the basal rot fungus are not needed there. In America the hot formaldehyde bath for nematode control is infrequently required; but chemical measures against basal rot are needed each year. Therefore, extensive field trials have been conducted here over many seasons to determine the best fungicidal materials and concentrations, and the most favorable time to apply these.

Chemical treatments are feasible at two periods in the annual cycle of narcissus growth: (1) in early summer between harvest and storage, and (2) in the fall before the bulbs are planted. Prestorage treatments were tested and recommended as early as 1931 by Weiss; but the necessity of drying the bulbs again before storing, and the greater danger of chemical injury to only partially matured bulbs, made the preplanting period preferable for early screening tests with fungicides. Preplanting treatments proved relatively safe, and the treated bulbs could be planted at once without the necessity of special drying; but treating at this period, of course, offered little or no protection against loss during storage. From the first various mercurials proved superior. Mercuric chloride, calomel, Calogreen, Semesan, Ceresan, New Improved Ceresan, and other proprietary mercurials proved effective in reducing rot, but all caused some injury. Two standard treatments emerged, a two-minute dip in 2% Ceresan (1 lb. to 8 gallons) for the Northwest, and a similar dip in New Improved Ceresan (1 lb. to 40 gallons) for the warmer Eastern sections. Such treatments came to be widely used, and have been fairly credited with saving the narcissus industry in the East. Treated bulbs far outyielded the untreated, and mercury injury was inconspicuous and accepted as inevitable. Although commercial growers were reluctant to use prestorage treatments because of the danger of severe injury to flowers, heavy losses from basal rot in storage turned the attention of workers to such treatments once more. Weiss, Haasis, and Williamson have reported on such tests, and further extensive experiments by Haasis remain unpublished. In screening tests of fungicides for preplanting dips, only mercurials, and notably New Improved Ceresan, afforded effective control of basal rot during storage. A dip of 2 minutes duration proved as effective as a 5-minute or 10-minute dip in preventing basal rot, and the shorter dip caused less damage to flowers. Treatments applied soon after the bulbs were dug (3 days) provided best protection against storage rot but also induced maximum flower injury, whereas late treatment (15 days after digging) caused no flower injury but afforded little protection against rot. In current commercial treatment, bulbs are now dipped for 2 to 5 minutes 3 days after digging in the East, and 10 days after digging in the Northwest, with fair protection against rot and minor injury to blossoms.

Recently McClellan has shown that dips in Mersolite 8 or Puratized Agricultural Spray afford protection against basal rot equal to the Ceresan dips, with no flower injury. These organic mercury materials have come into commercial use as prestorage and preplanting dips in North Carolina. Prestorage dust treatments in place of dips eliminate the necessity of drying the treated bulbs before storing them. Ceresan dusts recommended by Weiss in 1931 did not find favor because of the hazard of inhalation of toxic material by workers. Similarly Arasan dusts advocated recently by McClellan cause skin irritation to some individuals. Injury to narcissus by mercurials varies in severity with the variety. It may take the form of surface discoloration or root-plate pitting in the bulbs that are treated, or it may suppress or deform the flower that is differentiated within the bulb before treatment, and which should complete development several months after treatment. Spectrochemical studies by McClellan and co-workers have shown that mercury is absorbed by the bulb and concentrated in areas that are most subject to injury, namely the center and basal plate of the bulb and the developing shoot. McClellan and Stuart showed that basal rot is increased by heavy applications of complete fertilizers and by nitrogen fertilizers, particularly those carrying synthetic hormones or nitrogen bases. The causal Fusarium was stimulated by these organic nitrogen compounds when they were supplied in nutrient solution. Organic sources of nitrogen and excess nitrogen fertilization are now avoided by commercial growers of narcissus.

Summary: Twenty-five years ago Fusarium basal rot threatened to render narcissus culture unprofitable in the East. As research progressed cultural and storage practices were modified and fungicidal treatments devised that permit production of the crop even with relatively susceptible varieties and under climatic conditions favorable to the Fusarium. Basal rot is still present, causing some loss at times, but the security of the industry is no longer seriously menaced.

CONTROL OF DISEASES OF GLADIOLUS

The gladiolus has risen rapidly in importance during the past twenty years to occupy first place in market value among all florists' crops. The appearance of large-flowered long-stemmed varieties of good shipping quality expanded market demand and field production of cut blooms, until gladiolus appeared in every flower market, and in every month of the year in some. Such expansion of the gladiolus industry involves extensive shipments of planting stock and mass plantings in favored areas, two factors traditionally suited to dissemination and increase of diseases. As might be expected, disease problems have increased in number and intensity as the crop expanded. In 1916 L. M. Massey mentioned three diseases -- hard rot, dry rot, and scab -- as important in gladiolus. To these have been added Fusarium yellows and corm rot, Botrytis blight and rot, and Curvularia blight, which are major diseases, and a dozen other diseases of lesser or local importance.

Of the major diseases Fusarium yellows and rot caused by F. oxysporum f. gladioli, is a corm disease with secondary leaf yellowing. Botrytis blight (B. gladioli and B. gladiolorum), hard rot (Septoria gladioli), and scab (Pseudomonas marginata) affect both corms and leaves. Dry rot (Sclerotinia gladioli) involves a neck rot and corm rot. Curvularia blight (Curvularia lunata) affects leaves and flowers. The pathogens of all these diseases are corm-borne, and at least Fusarium, Sclerotinia, and the scab bacteria can persist in soil. Soil-borne diseases are avoided in part by rotation of fields, and often by moving to new land as long as suitable uninfested fields can be found. Chemical treatment of infested soils has not yet been applied commercially against these soil-borne pathogens of gladiolus. The production of disease-free planting stock has not been systematically developed, but corms produced in the cooler Northwest are prized for lower Fusarium infection. Sorting and chemical treatment of corms are not efficient enough to prevent introduction of pathogens into new areas, but are regularly used to reduce the severity of the corm-borne diseases. Preplanting treatment of corms has been intensively studied for years at several State agricultural experiment stations, and the New Improved Ceresan soak developed in Illinois has been of immense commercial value against Fusarium in Florida particularly, and in the East in general. Experience in Florida during the past year indicates that this New Improved Ceresan soak is providing less effective control than in former years, and that the problem is a continuing one. Cooperative studies by pathologists in several States have shown that different corm treatments are needed to cope with diseases that vary in prevalence in different areas. Prestorage treatments have been recommended recently from Florida. Spraying gladiolus for control of pests and diseases in the field was unheard of until the advent of the gladiolus thrips in 1930. Now Botrytis, Curvularia, and Stemphylium leaf diseases require regular applications of protectant fungicides, particularly in Florida.

Department studies, following the descriptions of diseases by Miss McCulloch mentioned above, have been concerned with factors affecting disease development, and with a search for disease resistance that can be used in a breeding program. McClellan, Baker, and Gould found the optimum temperature for the leaf blight phase of Botrytis to be 55° to 65° F., but corm infection was best at 35°, with little at 45° and none at 55° F. or above. Lack of corm infection at the higher temperatures is correlated with wound-periderm development which Ernst Artschwager and Ruth C. Starrett showed to take place most rapidly at higher temperatures and humidity. This behavior of Botrytis was found to be correlated with development of the disease in the field, areas with cool, moist growing periods proving to be subject to the foliage phase and those with cool, wet weather at harvest time experiencing Botrytis corm rot. The corm rot phase is now controlled in part by quick drying of the corms after harvest in areas with climatic conditions favoring Botrytis. Curvularia, on the other hand, is a disease of warm temperatures, the fungus having an optimum range between 75° and 85° F.

Studies of nutrition and fertilizer requirements of gladiolus by McClellan and Stuart have shown that the crop has a low nutrient requirement, and that excess nitrogen increases Fusarium corm rot and bacterial scab. Organic sources of nitrogen increase Fusarium rot more than do inorganic, and a low ratio of phosphate to nitrogen favors rot development. Modifications in the use of fertilizer in commercial gladiolus culture have followed these findings. Greenhouse experiments show that Curvularia leaf blight is more severe in gladiolus plants that are furnished high levels of nutrients.

Resistant varieties are eagerly sought by gladiolus growers as the simplest and most effective means of disease control. A large number of gladiolus varieties have been supplied to the plant breeders of this project, S. L. Emsweller and R. L. Pryor, by Thomas Manley of the Garden Center of Greater Cleveland, and by the North American Gladiolus Council. These are being tested for resistance to Fusarium corm rot and to Botrytis, Curvularia, and Stemphylium leaf spots by W. D. McClellan in cooperation with R. O. Magie of the Florida Experiment Station at Bradenton. Some degree of resistance is available against the leaf spot diseases. Resistance to Fusarium promises to be most difficult to establish and to incorporate in commercial types. In Miss McCulloch's studies Picardy proved resistant, but Fusarium later became so virulent on this variety that the disease was called "Picardy rot". McClellan found various isolates of Fusarium to differ widely in virulence for different varieties, showing that strain variation in the gladiolus Fusarium is a complicating factor. Magie has recently reported that Maid of Orleans, long regarded as highly resistant, is now proving susceptible to Fusarium in Florida, and that no commercial variety is known to be immune.

In order to conduct valid tests for resistance it is necessary to establish conditions favorable for infection and development of the disease. The identity of the pathogen, its capacity for variation, its temperature requirements, and the effects of nutrition on the gladiolus and on the pathogen itself must be known to avoid the danger of confusing escapes with resistant individuals. As indicated above, some studies have been completed by McClellan and coworkers and others are in progress. Much further study is needed in order to standardize screening tests for resistance that will select the genotypes from which better varieties can be synthesized.

DIVISION OF FRUIT AND VEGETABLE CROPS AND DISEASES, BUREAU OF PLANT INDUSTRY, SOILS, AND AGRICULTURAL ENGINEERING, BELTSVILLE, MARYLAND

THE DIVISION OF FOREST PATHOLOGY

Carl Hartley[1]

Focused research on forest pathology in the Department began at the turn of the century. It was first conducted, along with some fruit-tree pathology, at the Mississippi Valley Laboratory, under Hermann von Schrenk. In 1907 it was transferred to Washington headquarters, under Haven Metcalf, where it included forest and shade trees and shrubs and became recognized as the central research organization in this field. Responsibility for ornamental shrubs was later transferred to the Division of Fruit and Vegetable Crops and Diseases. The work can be divided into three periods: 1899-1912, primarily reconnaissance; 1912-1930, continued search for undescribed diseases and evaluation of damage, but with emphasis on protection against introduced epidemics, and in the West the extension of research into the interrelations of silvicultural practice and diseases on the National Forests; 1930 to date, with continuing work on new or introduced epidemics, but more intensive effort toward adjustments of forest management practices to decrease losses in both the East and the West, and increased attention to the deterioration of forest products. A brief historical treatment of the entire subject of forest pathology, including the developments in Europe, which preceded those in North America, is supplied by Hubert (79, Chapter 1).

THE MISSISSIPPI VALLEY LABORATORY

The Mississippi Valley Laboratory was established about 1899 at St. Louis, Missouri. Von Schrenk was the only worker until 1902, when G. G. Hedgcock (148) and Perley Spaulding were added to the staff. A little later Ernst Bessey and Caroline Rumbold joined it. During the lifetime of the laboratory, von Schrenk, an unusually versatile investigator, with Cornell, Harvard, and Washington University background, published a number of pioneer papers on decays in timber trees (126, 127, 128, 129, 130, 133, 135, 137), much like Hartig's work in Germany one to two decades before. Later his interests swung increasingly to decays of structural timbers and wood preservation with chemicals (131, 132, 136). The first activities of the rest of the staff were on fruit-tree diseases, including pioneer work on bacteria as the cause of apple crown gall and hairy root by Hedgcock, and on bitter rot of apples by Spaulding. Later forest pathology received most attention. Staining of sapwood in trees and lumber by fungi and dips to prevent such staining during seasoning were followed intensively by von Schrenk, Hedgcock, and Rumbold (134, 63, 117). Spaulding pioneered the culture of wood-decaying fungi and started studies on control of damping-off of confier seedlings, the first to use successfully inorganic acids for this purpose. The first comprehensive American publication on forest-tree diseases was issued (138). Von Schrenk's attention to impregnation of timber with chemical preservatives led to the controversy with the Forest Service that contributed to the discontinuance of the Mississippi Valley Laboratory in 1907. He remained at St. Louis as a private consultant for railroads and others on wood preservation, in the development of which he has continued to take a prominent part.

THE DIVISION OF FOREST PATHOLOGY

After the discontinuance of the Mississippi Valley Laboratory, Hedgcock and Spaulding were brought to Washington to form the staff of the new Laboratory, later Office, and finally Division of Forest Pathology, headed up by Haven Metcalf (1, 105), with the large budget of $14,000. Metcalf was then 31 years old and had specialized on diseases of rice and sugar beets. A man of broad scholarship and impressive personality, an independent thinker with a keen wit and gift of expression, he quickly commanded the respect of cooperators and the loyalty of assistants. After 1910 his duties were so largely supervisory as to permit little personal research, but in the first decade after the formation of the Division he published numerous coordinating and educative papers, samples of which are cited (106, 107, 108). He was a leader in the early development of the American Phytopathological Society; and partly from botanical or plant pathological and partly from forest school scources he built up a staff that made its imprint on forestry and arboriculture as well as on mycology and plant pathology. The new alignment was made with the concurrence of the Forest Service, under an interbureau agreement by which the subject of wood preservation was recognized as the primary responsibility of that Bureau. Cooperative relations were good; a committee set up to insure effective cooperation between the two Bureaus found so little need for its services that in a few years it faded out. While the older plant pathology Divisions, including the original Laboratory of Plant Pathology under Erwin F. Smith, and the Divisions of Fruit Diseases and of Truck Crop Diseases that sprang from it, have all since been incorporated in the Divisions dealing with the culture of the crops, the Division of Forest Pathology has continued as an independent research organization devoted principally to pathology. Its continued independence has been due largely to the fact that there has been no single crop unit into which it could properly be absorbed. Silvicultural research is in another Bureau. Nut culture covers only a few of the trees dealt with in forest patholgoy. Little varietal selection or other research in shade trees has been done in recent years in the Department, except that which has been incidental to the studies in Forest Pathology. To have distributed the tree disease work to the different crop research units concerned would have made necessary duplication of attack on many of the diseases.

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[1] A number of members of the Division have helped in the preparation of this paper, particularly Perley Spaulding, Glenn G. Hahn, George H. Hepting, and Agnes M. Ellis.

The major problem in 1907, largely responsible for first raising Forest Pathology to independent divisional rank in the Bureau, was the Asiatic chestnut blight, which had just been recognized as a potential devastator. Metcalf took personal charge of this work, initiating outside cooperation by part-time employment on it of J. Franklin Collins, Professor of Botany at Brown University, mechanical genius and expert on northeastern trees (144), and W. Howard Rankin of Cornell. Hedgcock was made responsible for a survey of the diseases on the National Forests, which he pushed with untiring energy. Spaulding took over the investigation of nursery and plantation diseases. He developed a broad acquaintance with European literature, which in 1909 led him to the discovery of the introduction and widespread establishment on pine in the Northeast of the white pine blister rust, which became the next emergency problem in the forest-disease situation. In 1909 Carl Hartley was added to the staff, and assigned to nursery diseases. In the same year C. J. Humphrey, at request of the Forest Service, was appointed; he was stationed at the Forest Products Laboratory of the Forest Service, for problems in the microbiological deterioration of wood. This arrangement for forest products has continued under the subsequent leadership of R. H. Colley and C. Audrey Richards for 40 years and resulted in the most intimate joint handling of commodity problems. The initiation of the next major line of activity of the Division was the appointment in 1910 of E. P. Meinecke, also at the specific request of the Forest Service. He was assigned to its San Francisco Regional Office, for adaptation of forest management practices to decreasing the incidence of heart rot and diseases in the National Forests and improving the salvage of infected stands. Meinecke had a wide background of European education and experience, including three years as assistant to Robert Hartig, founder of forest pathology. He promptly became a leader in constructive thinking in both pathology and silvics in this country. The outstanding success of this arrangement led to the appointment of J. R. Weir (153) and W. H. Long (154) to similar assignments in the Northwest and the Southwest respectively. The full-time appointment of Collins to shade tree disease investigation and inquiry correspondence, in cooperation with Brown University, in 1913, rounded out the organization of the work of the Division. An outgrowth of the shade tree work was cooperative disease survey and advisory work with the National Park Service, on the Parks, Monuments, and Cemeteries under its control. Emphasis in the epidemic diseases has been shifted from chestnut blight and blister rust to newer epidemics or threats of epidemics, which, under the successive leadership of R. Kent Beattie and Curtis May, have perforce received continuing attention.

Following the death of Metcalf in 1940, Lee M. Hutchins, known especially for his contributions to the physiology and pathology of fruit trees, was drafted in 1941 from the Division of Fruit and Vegetable Crops and Diseases to become Head of the Division of Forest Pathology. Under his leadership the strongly cooperative character of the work has been continued and extended. Active cooperation during the life of the Division has included not only the Forest Service, National Park Service, and Bureau of Entomology and Plant Quarantine, but also the Bureau of Ships of the Navy Department, the Housing and Home Finance Agency, Brooklyn and New York Botanic Gardens, Brown and Yale Universities, the New York State College of Forestry, the New Jersey State Department of Conservation, the Universities or Agricultural Experiment Stations of Idaho, Minnesota, Arizona, Georgia, Nebraska, Ohio, Pennsylvania, Maine, Wisconsin, Missouri, and Oregon and Pennsylvania and Kansas State Colleges. A beginning has been made at exploring the little-known field of virus diseases of forest trees (43, 47, 85, 155), on which in fruit trees Hutchins was the principal authority.

A recent summary of the situation of forest pathology is found in Hutchins' article in the 1949 Yearbook of the U. S. Department of Agriculture (84), which is followed by brief summary papers on each of the important activities. There are three American texts or manuals on the subject of forest-tree diseases (11, 4, 79), one of which (11) gives especially complete bibliography; and two that cover shade trees (36, 111), The picture as a whole is of an attempt to cover the diseases still largely in the reconnaissance stage that characterized the pathology of horticultural crops at the beginning of the century and of field crops to a somewhat later date. Special focus on a few of the hundreds of host species has resulted in islands of quite thorough coverage, usually on points bearing on practical application, but frequently on phases that have fundamental scientific value.

In the strictly reconnaissance stage of the earlier years, Spaulding, Hedgcock, Boyce, and Beattie gave considerable attention to the pertinent mycological and pathological literature, both American and European. On the applied phases of the subject developed later, there was relatively little to be learned from the literature until quite recently, and attention to the literature has decreased, dependence being largely put on the Boyce index, the recent textbooks, and the excellent abstracts included in the Review of Applied Mycology. Card indexes developed by Spaulding and Hedgcock in early years at Washington, and more recently by Spaulding at New Haven, and by Boyce in connection with his manual (11), have aided other investigators. By a cooperative arrangement the Boyce index has been reproduced and sets have been furnished to branch offices of the Division. Formal extensive bibliographies on the chestnut blight (5), the Dutch elm disease (41), and diseases of cinchona (94a) have been published, and the three white pine blister rust bulletins by Spaulding carried bibliographies totalling several hundred titles (145a, 146, 147a).

Another valuable working tool is the reference collection of translations of important foreign-language articles in the forest pathology field, initiated by Gravatt during the 1930's. Languages such as Russian, Japanese, Dutch, and Italian, unfamiliar to most American pathologists, were particularly emphasized, and a total of 800 translations are now available for use. These and many unpublished reports are available for loan to active investigators of the subjects.

PRINCIPAL LINES OF WORK

FOREST NURSERY DISEASES: Though the total area of forest nurseries has never been large, their importance to the forest planting program and the applicability of intensive control measures in nurseries warranted special attention. Intensive studies and service activities mainly to State and Federal nurseries continued until 1920, and were resumed in 1935 at the time of the forest and erosion-control planting expansion on funds made available by the Civilian Conservation Corps and the Great Plains Shelterbelt Project. Most of the important nursery diseases then recognized were brought under a degree of control that made them no longer important limiting factors on planting operations. Exceptions included the Phomopsis blight of red cedar, which continues periodically to prevent the production of the stock required for field planting (29, 51), and some obscure root diseases. One of these was about to force the abandonment of one of the largest southern pine nurseries; recently it was found readily controllable by some of the soil fumigants employed for nematodes (92). Cedar blight is better controlled by mercurials than by other fungicides tried by Slagg and Wright, but requires too frequent spraying through the entire summer. Conifers have received the major part of the attention, since nearly all forest planting is with conifers and their diseases were causing more interference with production schedules than were those of the broadleaves. The finding in 1909 (54) that much so-called damping-off was due to heat lesions on the stem near the soil surface led to better seedbed management and stimulated recognition by foresters of high temperature at the base of the stem as a direct cause of much of the seedling mortality in natural forest stands. The recognition of a supposedly parasitic disease of older stock in some of the western nurseries as really an unusual type of drought effect, saved one of the early planting projects from discontinuance (53). The finding of an important relation of damping-off to soil nitrogen and pH, and its control on soils of intermediate pH by various inorganic acids, including orthophosphoric, and also by aluminum and ferrous sulfates, was one of the principal outcomes (29). One of the early indications of antibiotic action affecting a plant pathogen came out of the damping-off studies (55, pp. 82-84). The effect of the damping-off fungi on conifer seed was also demonstrated. The effort to protect southern pine nursery stock from the fusiform stem rust has led to an interesting development. Better control is obtained if a fungicide is applied to the burlap used to cover the bed while the seed is germinating as well as applying fungicide later to the seedlings.

NATIVE FOREST DISEASES: Loss from killing diseases in the forest, as pointed out by Meinecke (103), is not properly measured in terms of percentage of trees killed, but rather in percentage of the area of the stand that becomes understocked because of the disease. Damage also depends on whether the disease tends to kill the most vigorous trees as do the stem rusts, or the poorer trees as do most of the facultative parasites.

There have been notable contributions, particularly by pathologists at forest schools, but until recently the State Agricultural Experiment Station pathologists have left most of the job to the federal government. This unfortunate hesitance has been partly due to the feeling in many quarters that nothing much can be done to prevent forest disease. The commercial forest area is greater than the area in cultivated crops, but unit values of forest land are relatively low. Against the cost of most disease preventive procedures there must be many years of compound interest charges before the timber is harvested. Intensive direct-control measures are rarely practicable. The use of fungicides, even in shade tree work, is relatively small (58). However, loss can nearly always be decreased by changes in forest management or utilization after the effects on disease of different timber management practices are sufficiently well understood.

In the West the early studies on the National Forests discovered or evaluated many unrecognized or little known diseases (64, 96, 101, 104, 164, 165). In the East, work on the native forest diseases advanced little until it became possible late in the 1920's to put pathologists at three of the new Forest Service Experiment Stations. At all of the stations maintained at the Forest Service field headquarters, a large amount of the attention has been to heart rots in the living trees (74). This is the most important single type of damage in old-growth forests, and is estimated as responsible for annual losses of 1-1/2 billion board feet of saw timber (2, Table 1). Information on the age at which decay can be expected to become serious helps in management planning. For example, Lake States aspen generally should be cut at 50 years of age, northeastern balsam fir at 70 years, and Appalachian scarlet oak at 120 years to avoid heavy cull. In some other species, decay is unimportant to a high age, except in stands of sprout origin or those injured by fire. Better acquaintance with external signs of heart rot makes possible more intelligent selection, bucking, and log grading and thus more economical utilization of infected stands (8, 102, 151, 73). Quantitative studies of the decay that starts at fire scars have also been applied to the establishment of fire damage claims (68) and decisions as to how much of the forest management budget should be allocated to fire prevention.

More important for the long pull, it has been found that by proper selection in thinning, or in selective logging of older timber, the more susceptible trees can be eliminated and heavy decay losses avoided in the residual stand. Trees are taken out if they already show signs of infection, or if they are bad decay risks. These would include trees that originated as sprouts from stump buds above ground line or that have large trunk wounds or large dead branches or mistletoe brooms through which decay can enter readily.

Such indirect approach to disease prevention, initiated by Meinecke in California (102), was early extended by Weir and Hubert in the northern Rocky Mountains (164), by Boyce in the Pacific Northwest (8), in the 1930's by Spaulding, Hansbrough, and associates in the Northeast (151, 150, 147, 16, 142), by Hepting, Lindgren, and associates in the oak type (115, 69, 67, 86), by Gill and Andrews in pine in South Dakota, New Mexico, and Arizona (3), and by Childs, Englerth, and Wright in the Pacific Northwest (166, 18, 35, 34). Parallel with these practical studies went the identification of the fungi that cause heart rots in a number of important tree species, in which, as with other diseases, the field workers were greatly helped by the intensive mycological studies of Davidson and associates (14, 15, 28) and by the Division of Mycology and Disease Survey at Beltsville. An unexpected development in a pine canker found due to a Fusarium, was the ability of the fungus to stimulate turpentine production when applied to trees artificially (71).

Another type of disease that could be decreased to an important degree by selection of sound crop trees in stand improvement thinnings, is that of the bark cankers, notably Nectria (42), Strumella, and others in eastern hardwoods (69, 67, 150). Nectria canker on yellow-poplar is one of the few well established cases in which forest trees can overcome established infections as a result of artificially improved growth conditions (in this case produced by thinning). Tympanis canker of red pine (52) is an example of the numerous diseases that are important only on trees planted outside the natural, or at least the optimum, range of the species; and in this case, even out of its range, damage can be mainly avoided by properly timed thinning. In this case, as in Valsa sordida canker of true poplars (11), Phomopsis lokoyae on Douglas-fir (9), and others, drought predisposes to infection. Nitrogen feeding, which greatly increases the incidence of damping-off in conifer seedbeds (55), at least temporarily cures the Phytophthora-associated littleleaf disease of shortleaf pine (116). This latter disease is important only on the less permeable soils (24), on which also the Phymatotrichum root rot is most severe in southwestern shelter belts. After further study, forest plantations can be safeguarded from such diseases by choice of species or geographic form appropriate to the site that must be planted, or conversely by choosing sites appropriate to the species to be grown.

Sanitation, in the sense of removing sources of infection, has not proved practicable in most of the cases for which it has been seriously considered. A trial of eradication of Nectria and Strumella cankers in oak was a failure.[2] The very destructive dwarf mistletoes (39, 88) of the

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[2] Hepting, G. H., and Elmer R. Roth. Eleven years' results on canker control on the Swallow Falls State Forest, Maryland. 7 pp. (typed). 1944. Unpublished report.

Rocky Mountain and Intermountain Regions have been the principal exception to this. Elimination of old infected trees and pruning out new infections is a practicable protective procedure in many places (40). Another important exception is the use of fire. Prescribed burning has been shown very helpful against the brown-spot needle disease of young longleaf pine (140) and has been considered for removing old pine stands ruined by dwarf mistletoe and for completely cleaning out ribes from Idaho white pine land preparatory to new planting.

The numerous native rusts of conifers have received much attention. Meinecke, Hedgcock, Bethel, Spaulding, Weir, and Hubert did pioneer work in separating them and locating the alternate hosts of the heteroecious majority, recently summarized (10, 65). But removal of alternate hosts has not proved practicable for most of the rusts, even in the neighborhood of nurseries, and in the special case of the very troublesome Cronartium fusiforme on southern pines, Siggers (141), Sleeth, and Lindgren (91) have shown paradoxically that controlled burning or the removal either of infected leaders or of entire infected trees from plantations tends to favor rather than to prevent new infections in the residual stand. The bad effect of thinning or of pruning leaders results from the fact that the rusts, like other obligate parasites, are better able to infect the lush growth that follows these procedures. Other examples of predisposing effect of thinning have been found in the dwarf mistletoe of lodgepole pine (oral communication by the late Carlos G. Bates); and for a quite different reason, in Fomes annosus attack on roots and butts of white pine (72), in which the roots of the felled trees serve as feeder material for the Fomes. Sanitation procedures are unusually difficult subjects for experiment, since test plots in most cases must be so large that replication is expensive and intimacy of comparison is lost. They have not been extensively tested, and after more attention additional fields of application presumably will be found.

The work on virus diseases, previously referred to, has gone far enough to indicate that a thorough study will show the woods to be full of them. In locust (43) and also in elm, intensive study of one virus disease soon showed that others were also present. The locust brooming disease, and probably most native forest viroses, can be expected to become important only where vegetative propagation replaces the present practice of reproduction by seed.

Root diseases have been studied, but because of the obvious difficulties in both research and its practical application under forest conditions, no great advance has been made (112, 113). Most attention has been given the very damaging dwarf mistletoes of northern and western conifers (165, 88).

Interrelations between forest diseases and forest insects are numerous and often important. One of the surprising ones, first recognized by F. C. Craighead of the Division of Forest Insect Investigations, is the apparent need of the important scuthern pine bark beetle for the help of a specific associated Ceratostomella in its attack on the pine (118, 110). This fungus, C. pini, is practically never found except in trees attacked by beetles of the genus Dendroctonus, and is universally found with the southern pine beetle. Cooperative studies have indicated that the actual killing of the tree is by the fungus, after the beetle has done a thorough job of inoculating the tree with it; and that otherwise the trees would probably be able to drown out the beetle and escape the devastation that it often produces. While the practical problem of prevention remains with the entomologists, strictly considered it is merely a vascular wilt dependent on a specific insect vector. Somewhat similar symbiotic attack occurs in less-studied bark beetle-wilt fungus combinations that cause periodic devastations of large forest areas (118).

Resistance to native diseases is being determined cooperatively on the hybrid poplars and pines that the Forest Service is developing (20) and remarkable decay resistance of the wood has been demonstrated for two black locust selections of the Soil Conservation Service. Several factors, including the time required for the plants to reach seed-bearing age and the fact that most forest reproduction must be by natural seeding rather than by artificial seeding or planting, operate to keep the genetic approach in forest pathology from having as wide usefulness as it has in the case of food crops, and thus to remove one of the principal advantages of integration of cultural and disease research in a single Division. The genetic attack has larger possibilities for shade trees and will be discussed further in connection with introduced epidemic diseases. However, if forest or shade trees were made much less heterozygous in an effort to improve them, and particularly if this were carried to the point of making plantings of single clones, more rather than less disease damage would likely result (56).

NATIVE SHADE TREE DISEASES: The earlier work was perforce scattered and largely of a service type, because of the large volume of inquiry correspondence that had to be handled and the great number of tree species that it covered. Early attention was paid particularly to the art of tree surgery (23, 98, 38); Metcalf and Rush P. Marshall took the initiative in establishing and actively helped to develop the National Shade Tree Conference, an organization primarily of commercial shade tree men, which has helped in the improvement of technical and ethical standards and the change in emphasis from cavity filling to more efficient forms of tree care and protection. Advances in knowledge have been chiefly in etiology and general hygiene (100, 97). A notable practical achievement was in the finding that the disastrous canker-stain of the much planted anthracnose-resistant London planetree could be stopped by simply restricting pruning to a safe time of year, or disinfecting pruners' tools and equipment (162). Susceptibility studies of shelterbelt plantings to *Phymatotrichum* root rot are mentioned elsewhere.

EPIDEMIC DISEASES, INTRODUCED OR OF UNCERTAIN ORIGIN (47): These have kept the center of the stage in both forest and shade tree disease work, particularly in the East, during a considerable part of the life of the Division. The periods of most concentrated research effort on the major epidemics were roughly: for chestnut blight, the decades following 1907 and 1924; for white pine blister rust, 1915 to 1925 in the East, and to 1940 in the West; and Dutch elm disease and elm phloem necrosis (155), 1932 to date.

Diseases that have appeared threatening but have received less concentrated or less prolonged attention thus far, include European larch canker, willow scab, the *Cephalosporium* canker of persimmon, *Fusarium* wilt of mimosa (66), the *Nectria* that kills beech weakened by the European scale (149), the *Chalara* wilt of midwestern oaks, the devastating dieback of birches in the Northeast, the pole blight of Idaho white pine, and the littleleaf syndrome of shortleaf pine. The last two are considered by their investigators at least as likely to be of native as of foreign origin.

Temporary epidemic threats, due to fungi that apparently are native rather than introduced, included the lokoya canker of Douglas-fir (9), and the *Atropellis* twig canker of hard pines (30). In addition, study was made in Europe by Hahn and Boyce of epidemic diseases that were feared as possible invaders of this country, but were found to be in fact native to North America and invaders in Europe (11, pp. 151 and 155).

Chestnut blight, caused by *Endothia parasitica*, has provided the spectacle of practical extermination of a widely distributed major species within a 50-year span. Metcalf early recognized its probable Asiatic origin (106). An eradication effort (108) was made in 1912-14 by the States of Pennsylvania and Virginia with cooperation by the Division. It became evident that even at the first discovery ten years earlier the fungus had spread too far to allow eradication. The disease reached the extreme limits of the range of the species within 40 years of the supposed date of first entry, killing most of the chestnuts in any particular locality within about 15 years after establishment. The numerous reports of comeback on the part of the chestnut have proved to be due to temporary escape, or the development of seedlings or sprouts for a few years in places where the old trees had been so completely killed that the fungus had died out locally from lack of a differential substratum and had not yet returned. Its more recent spread in Italy is causing concern (46).

The white pine blister rust, caused by *Cronartium ribicola*, (99, 107, 146, 90) entering independently on both East and West Coasts by or before 1910, has spread through nearly all of the range of the three commercial white pines, thus far causing little loss of timber of merchantable age but with much damage to young stands and indication that the commercial range of the two important western species may be considerably restricted by it despite all practicable control efforts. Of the other epidemic diseases, the most serious damage thus far has been to the beauty of numerous towns and cities by the two elm diseases and by mimosa wilt; the general dying of the commercial birch species in the eastern two-thirds of Maine; and losses of stumpage values estimated by the Forest Survey and Division of Forest Pathology at $5,000,000 per year from the littleleaf disease in shortleaf pine in the Piedmont. Oaks in places in Iowa, Illinois, and Wisconsin, beeches in places in the Northeast, and white pines in pole blight locations in Idaho have been hard hit; but the outcome of these and some others of the epidemic diseases listed can not yet be certainly estimated.

The first work on most of these epidemics was to determine their extent (37) and rate of spread, and whether they really were of foreign origin. In the case of chestnut blight and blister rust, some of the well known mycologists in the Northeast denied that they were of foreign origin. Therefore, the studies included Asiatic and European exploration and critical taxonomic and cross-inoculation studies, in some cases with monographic treatment of entire genera or parts of them: e.g. Shear et al. on *Endothia* (139), Hedgcock, Bethel, Colley, and associates on *Cronartia* found on *Ribes* (22, 64a), Hahn and Ayers on *Phomopsis* (48, 51), *Adelopus*, and *Dasyscypha* (50), Snyder et al. on the mimosa *Fusarium* (145), Lohman et al. on *Atropellis* and *Nectria* (93, 94), and Davidson on *Ceratostomella* (25, 26). The chestnut work included classical studies of means of transmission by F. D. Heald and associates (62), and study by G. F. Gravatt (45) and others of rate of spread that aided in planning utilization of the timber.

The larch canker bridgehead has apparently been destroyed by eradication. This was possible only because of the practical inability of the causal Dasyscypha to spread on the eastern larch in whose range the invasion occurred. This success, therefore, does not constitute evidence that eradication is likely to prove possible against really dangerous invasions from abroad.

White pine blister rust (99, 109, 146) is the one forest disease in which sanitation in the sense of removing infection sources has played an important role in local control. The eradication of the ribes (currants and gooseberries) that are the alternate hosts was started by Spaulding in 1909, and expanded into a campaign in 1916, under the leadership of S. B. Detwiler. After its practicability for control of the rust was demonstrated, its expansion was set up as a separate Division of the Bureau of Plant Industry in 1919, and transferred in 1934 to the Bureau of Entomology and Plant Quarantine, which has carried it on as a several-million-dollar program since that time. The numerous lines of research on the fungus, fundamental to the success of the sanitation program, were carried through by the Division of Forest Pathology, while studies of ribes ecology and methods of ribes control have been by the action agency. The eastern white pine, with the aid of the control program, continues to be a principal commercial species. The greater susceptibility of Idaho white pine, the greater cost of ribes eradication in some places in Idaho, and delayed availability of funds, have limited the area on which this species can be protected. Fire has been proposed as a last-resort method of reestablishing healthy stands in places. The rust has more recently invaded the region of the still more susceptible sugar pine in California and Oregon, where the results of control efforts thus far are encouraging.

The introduced epidemics have been the only forest-tree diseases for which there has been a serious attempt to develop disease-resistant varieties of trees (20). In elm, persimmon, mimosa, and white and sugar pines, enough resistance to their introduced parasites has been found to offer much promise. In the case of blister rust, contribution has been made to control by the discovery or promotion of varieties of cultivated Ribes that are immune or nearly so to the rust (49). In the case of chestnut blight and Dutch elm disease, interspecific hybridization has been employed to make use of the resistance of Asiatic species unpromising for direct forest planting, and the Asiatic orchard chestnuts and ornamental elms have been used directly. Selection will apparently provide an ultimate solution of the mimosa wilt problem. Interspecific pine hybrids developed by the Forest Service are also being tested against white pine blister rust.

An historical development on which the introduced tree diseases had a large influence was that of port inspection and quarantine. Until 1912 there was free trade in plant pests. There was no port inspection, and even if a dangerous disease were found on a shipment of plant material from abroad its destruction could be required only by the State Nursery Inspector in the State to which it was consigned. With the horrible examples of the chestnut blight and blister rust to aid him, Metcalf took a leading part, against the opposition of nurserymen who were importers and of some of the most prominent pathologists and mycologists of the time, in urging protective legislation. After the passage of the Simmons Act and the setting up of the Plant Quarantine Board, there was still hesitancy in establishing regulations that made full use of the powers conferred on the Board. In 1917 Metcalf, Detwiler, and R. Kent Beattie[3] were finally instrumental in getting provisions that could be reasonably effective in hindering the entry of foreign diseases on introduced propagating material. Few seed-borne diseases are known among forest and shade trees, and there is reasonable doubt as to the need for restrictions on seed movement. No action has been taken on the recommended requirement that logs generally be peeled before admission, the need for which was highlighted by the entry in unpeeled logs of the Dutch elm disease (6).

DETERIORATION OF FOREST PRODUCTS (57): One of the useful early reconnaissance activities in this field was on sanitary storage practices for lumber (80). During World War I there was a sudden expansion of work on the pathology of wood and its products. Problems were presented in the storage of paper pulp, the production of vehicle stock, and particularly evaluation initiated by Meinecke of the little-known discolorations and defects in airplane wood, for the study of which military funds were made available. These war needs brought into the products field C. Audrey Richards, R. H. Colley, and temporarily a number of others, and led to four Department or Technical Bulletins (76, 89, 125, 7).

The second expansion was in connection with the acute need for control of sapstain or blue stain of lumber that arose with the increase in the percentage of sapwood in the young-growth southern lumber in the late 1920's and the difficulty in selling sapstained lumber that was experienced particularly by the important lumber export trade. Partly with funds contributed by the exporters, products pathology work was set up in cooperation with the Southern Forest Experiment

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[3] R. Kent Beattie came to Forest Pathology in 1912, but in 1913 went into the employ of the Board. He later returned to Forest Pathology.

Station of the Forest Service, under R. M. Lindgren. This promptly led to the finding of efficient mercurial and chlorophenolic dips for lumber and treatment for logs, the former being at once adopted by the industry, which within a decade was dipping approximately a sixth of all the lumber produced in the country, or about half of the lumber of the grades that needed it (124, 156).

The next large expansion of the products work was in connection with World War II, in which the need for a wider range of woods for aircraft required additional studies of discolorations suspected of being signs of incipient decay (119). Glues used in plywood, containers for military supplies, and safe construction and maintenance of wood training planes, gliders, ships, and war housing all posed problems that had not before been so acute. Since a large amount of unseasoned lumber was shipped, dipping was needed even more than during peacetime to prevent decay as well as stain during transit and storage. Furthermore, there was at times a scarcity of mercurials and chlorophenates on which stain control was mainly dependent. The number of questions that arose and the short time in which they had to be answered made the activity largely one of advising on the basis of existing knowledge or hasty and superficial tests. However, much was learned from the studies, as for example the importance of bacteria in protein glue deterioration (19), the decay resistance of different oaks (122), the significance of discolorations of aircraft woods (119), the demonstration that decay in aircraft was due not to moisture condensation but to avoidable failures in drainage (70), and the value of mixtures of fungicides, particularly with the addition of borax, in preventing decay as well as stain of green lumber, and at low concentrations that avoided skin irritation from the chlorophenates, made possible conservation of the chemicals (159).

Decay in buildings has received much intermittent attention and at present is a major interest because of the housing shortage, and some added hazards due to changes in construction methods and materials. The proposal by Scheffer and demonstration by Diller that frame houses without basements could be protected from the winter condensation moisture that leads to decay of sills and joists, by laying roll roofing on the soil surface under the house (31) was a particularly valuable contribution. The distinctive and destructive water-conducting capacity of Poria incrassata (82, 114) was one of the early subjects of study, followed by the more recent demonstration that it is surprisingly susceptible to drying (120, 121). While most parts of a building and even of a boat can be most simply safeguarded by protecting them from excessive moisture (157, 59, 75, 32), there are some parts that must depend on very high natural resistance to decay, or on fungicides. It is still difficult in many places to get lumber at retail yards that has had standard wood preservative treatment and the simpler dip or brush applications of fungicides that can be given in the course of construction have become of interest. These have been in laboratory tests and in outdoor trials on wood not in contact with the ground, under otherwise severe exposure conditions; while they are still to be regarded as makeshifts, tests thus far indicate that they have a considerable field of usefulness (157).

More fundamental contributions begun in the early cooperative studies with the Forest Products Laboratory included the relation between the decay resistance of the durable heartwoods and the toxicants in their hot-water-soluble extractives (61, 163). Basic contributions also included studies of decay diagnosis and classification (78, 27), reactions of decay fungi to temperature and toxicants (83, 60, 143, 77), moisture requirements for fungi in wood (21, 93), and improvement of methods for accelerated laboratory tests of the fungistatic value of new preservative chemicals (113, 81, 158) or combinations of these (33).

A field activity related to that of products pathology was the study of deterioration of killed timber in the woods, as an aid to planning salvage programs. Fire (87), hurricanes, insects, and chestnut blight have killed standing timber over great areas, and a number of quantitative studies have been made of the length of time during which the dead trees remain in condition to be utilized. Periods of usability have varied from 2 or 3 years in low-elevation conifers to 20 or 25 years in high-elevation conifers for pulp, and in chestnut for tannin extraction (12, 45). An unclassified activity that may also be mentioned is the study of the rate of decay of logging slash, a matter of much importance in forest management in some regions where it is desirable to have rapid decay and thus shorten the period in which the slash constitutes a serious fire risk. This type of study, pioneered by W. H. Long in southwestern pine and oak, has been extended to other types (152, 95, 17).

One of the contributions of the products pathology project is the part it has had in training men for later work for industrial concerns. Commercial effort in wood protection had previously been almost entirely by chemists and engineers. Pathologists formerly in the products work of the Division are now in responsible jobs with three of the companies that are pushing the newer wood protective chemicals, and in the industrial laboratory that has the largest concern in wood protection.

The following tabulation will serve instead of a summary, though it contains a few items not covered in the text.

Table 1. Summary of Forest Pathology activites.

SUBJECT Phases emphasized	Periods of special attention	Important findings or control developments
NURSERY DISEASES		
Damping-off of conifers	1907-20, 1933-41	Successful control by using acid soil and restricting nitrogen fertilization, or by treating soil with acids or acidifying sulfates; but not by withholding water.
Southern pines diseases	1929-date	Fusiform rust controlled by precisely timed spraying with organic fungicides, not by alternate host eradication. Needle brown spot easily controlled by Bordeaux; obscure root disease by soil fumigation with nemacides.
Other diseases, mainly conifer	1907-18, 1935-41	Correct diagnosis of a number of previously confused diseases led to control of most important ones except *Phomopsis* blight of cedar and certain seed failures.
NATIVE FOREST DISEASES		
Survey in West	1908-22	Numerous diseases discovered or evaluated. Life cycle of many heteroecious rusts determined.
Survey in East	1925-40	
Longleaf pine needle brown spot of seedlings.	1929-41	Control by fire as a sanitation measure.
Hypoxylon canker of aspen	1949-date	50 plots in Lake States in environmental relation study.
Septoria canker of tree poplars	1945-date	Many Forest Service hybrids tested for resistance; 19% appear resistant.
Trunk cankers, eastern hardwoods and red pine	1933-40	Selection of safer sites for plantations; release from competition for yellowpoplar and red pines; selection of low-risk trees for future crop.
Fusarium canker of southern pines	1945-date	Harmful to some species; stimulates pitch flow and may be useful in inducing commercial turpentine production from scrub pine.
Fusiform stem rust of southern pines	1930-date	Nearly disease-free stock for planting can be secured by nursery spraying and roguing. Pruning infected side branches from youngest trees; but not infected leaders.
Dwarf mistletoes, western conifers	1910-date	Recognition of magnitude of damage; removal of old trees that would infect young stands, and control of recent infection by pruning.
Sap streak, sugar maple, N.C.	1940-date	*Endoconidiophora* wilt; spread being studied.
Mortality after beetle attack, shortleaf pine	1928-31	Beetle-carried *Ceratostomella* the actual cause of death in bark beetle epidemics.
Cotton root rot, Okla. and Texas shelterbelts	1935-date	Least on sandy soils. Hackberry and junipers resistant; elms, legumes and American pines susceptible.

Table 1. (Continued)

SUBJECT Phases emphasized	Periods of special attention	Important findings or control developments
Native Forest Diseases (Continued)		
Root rots, western pines and Douglas-fir	1938-date	Etiology, effect on liability to bark beetles, and effect on stand density and yield.
Heart rots		Advances in etiology. Information on external signs of heart rot and relation of decay cull to age, making possible more intelligent harvesting of infected stands (firs, oaks, western hemlock). Practices for avoiding infection of young stands; fire control and careful logging to avoid wounds that decay can enter; in thinning operations the selection of low-risk trees as crop trees; and pruning lower branches of ponderosa pine before age at which decay can enter through them.
Pacific Coast firs	1910-28, 1945-date	
Eastern fir, oaks, yellowpoplar, black cherry, paper birch	1928-39	
Western hemlock and Rocky Mountain ponderosa pine	1933-date	
NATIVE SHADE TREE DISEASES		
Tree surgery	1913-46	Determination of best season for pruning; discouragement of too much cavity filling; Farmers Bulletin on tree repair and avoiding damage in construction work.
Canker stain of London planetree	1935-42	Control by observance of safe pruning dates or by disinfection of pruning tools and ethyl mercury nitrate in wound paint.
Wetwood in poplars, willows, elms, oaks, etc.	1932-39	Association with bacterial infection, increased wood pH, slime flux, and in Lombardy poplar early mortality.
Mosaics and brooming diseases	1928-30, 1937-date	Graft transmissibility demonstrated in locust, elm, and walnut; seed transmission in 2% of elm.
Verticillium wilt of		Can be partly controlled by fertilizing and watering.
maple	1923-28	
elm	1932-38	
Dothiorella dieback of elm	1932-38	Control by pruning.
Coniferous needle diseases in the Northeast	1940-48	Control by spraying.
EPIDEMIC DISEASES, INTRODUCED OR OF UNCERTAIN ORIGIN		
Chestnut blight	1907-	*Endothia* monographed to distinugish causal fungus from confusing relatives. Pioneer studies of dissemination. Pacific Coast infections eradicated. Rate of spread and of deterioration of killed timber studied as aid to salvage of old stands. Resistant Asiatic species introduced and crossed with American.
White pine blister rust	1912-45	Control by alternate host removal. Morphological and life history studies, to distinguish from confusing native species.

Table 1. (Continued)

SUBJECT Phases emphasized	Periods of special attention	Important findings or control developments
Epidemic Diseases (Continued)		
Dutch elm disease Elm phloem necrosis	1930-date 1930-date	Introduction of "Dutch" disease traced to imported veneer logs. Insect transmission; route and rate of internal movement through the tree and external dissemination; new methods for elm propagation; discovery of resistant strains which are being multiplied.
Phytophthora cinnamomi root rot	1933-40	Nineteenth century recession of chestnut, current decimation of Ozark chinkapin, and root rot of small numbers of other species connected with this fungus.
Littleleaf disease of shortleaf pine	1929-date	Relation to soil permeability, nitrogen deficiency, and abundance of *Phytophthora cinnamomi*; decrease in losses by adjusting cutting age on predisposing soils.
Mimosa wilt	1929? -date	Resistant clones now being multiplied; resistance transmitted by 50% of seed if from resistant trees.
Coryneum canker of Monterey cypress	1928-45	Cause determined and relative resistance of North American *Cupressus* species tested.
Willow scab	1932-40	Serious damage to some northeastern species; also now widespread in southern Appalachians. No intensive studies.
Dasyscypha canker of larch	1934-38	Found on European larch 20 years after introduction; low virulence on eastern larch; all known cases eradicated.
Pole blight, Idaho white pine	1949-date	Distribution in northern Idaho determined by airplane survey; etiological research in progress.
Birch dieback	1948-date	Devastating disease surveyed for distribution; associated ring spot exonerated; cause unknown.
Chalara wilt of oaks	1940-42, 1949-date	Cause determined, Survey started
Beech-scale *Nectria* disease		A weakly parasitic *Nectria* following scale infestation and causing widespread dying.
DETERIORATION OF WOOD AND ITS PRODUCTS		
Decay of logging slash Southwest Northeast	 1913-18 1925-30	On most sites, decay is favored and period of fire risk shortened by slash disposal methods cheaper and simpler than those formerly prescribed.
Deterioration of killed timber Hurricanes, Northeast and Northwest Fire, Oregon Fire, California	 1921-42 1930-40 1947-date	Determination of length of time during which the timber is worth salvaging. For Utah and Colorado beetle-killed spruce for pulp, and chestnut for tannin extraction and pulping, salvage plans materially aided by finding that utilization could continue for 20 years.

Table 1. (Continued

SUBJECT Phases emphasized	Periods of special attention	Important findings or control developments
Deterioration of wood (Continued)		
Insects, Utah, Colo., and Northeast	1947-date	
Felled for beetle control, Northwest	1922	
Chestnut blight	1923-33	
Decay of logging slash and deterioration of forest products		See last pages of text.

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DIVISION OF FOREST PATHOLOGY, BUREAU OF PLANT INDUSTRY, SOILS, AND AGRICULTURAL ENGINEERING

PLANT NEMATOLOGY RESEARCH IN THE BUREAU OF PLANT INDUSTRY, SOILS, AND AGRICULTURAL ENGINEERING

G. Steiner

ORIGIN AND HISTORY OF PROJECT

Nematodes were first observed to cause crop damage by Needham in England, who in 1743 discovered the so-called wheat nematode in galled wheat kernels. In this country damage related to plant nematodes is said to have been known in Florida as early as 1805, when galled and knotty malformations as they are produced by the root-knot nematode, were first noticed on roots of various crop plants. The causative organism was not discovered, however, until about three quarters of a century later. In the year 1889 the first three papers on plant nematology were published in this country; one by G. C. Neal on the root-knot disease of the peach, orange, and other plants in Florida, Bulletin No. 20, of the then Division of Entomology, U. S. Department of Agriculture; a second one by G. F. Atkinson, on nematode root-galls, Bulletin No. 9, of the Agricultural Experiment Station of the State of Alabama; and a third by F. Lamson Scribner, Bulletin No. 2, Volume 2 of the Agricultural Experiment Station of Tennessee. This last publication reports two different diseases of potatoes caused by unnamed nematodes. Today these diseases can be identified: one is that caused by the root-knot nematode, and the other that caused by Scribner's meadow nematode. In 1907 a separate unit for the study of plant and soil nematodes was set up in this Bureau with the establishment of a Division of Agricultural Technology. The major part of the work of this Division covered nematology investigations. The title of the Division was changed to Division of Nematology in 1928.

THE OVER-ALL PROBLEM

Nematology has been, and still is, a much neglected science. Nematodes are one of the largest taxonomic groups of the animal kingdom, but the least known from an over-all viewpoint. Aside from the parasites that attack man and vertebrates and a few forms attacking plants, they have never been made the subject of concentrated research efforts. The larger part of existing nematode species is still undescribed. This is particularly true of the marine forms and of those living in the soil. The present general conception of nematodes is, therefore, mainly patterned after what is known of the parasites of man and vertebrates. In reviewing the problems of nematology as related to crop production, it is thus necessary to point out that in this particular field, applied science has suffered more than elsewhere from a lack of comprehensive fundamental information. There exists here a diversity of basic taxonomic, morphological, physiological, bionomic, geographical, and economic problems that necessarily should be studied to implement the efforts for the control of noxious types of nematodes and also the attempts at a better understanding of other phases of the significance for crop production of the group as a whole. The work under the present project of the Federal Bureau of Plant Industry, Soils, and Agricultural Engineering centers on the problem of crop and plant protection, particularly how to reduce losses and detrimental effects, and how to promote beneficial action of nematodes in this regard. Adjunct activities cover such problems as that of the vinegar eel in its relation to the vinegar industry, or that of fresh-water nematodes in drinking water supplies, or that of marine forms in disposal plants, and other similar nematode problems arising from the activities of man.

Progress of this nematode project has been hindered through the fact that the subject matter has not been taught until recently at colleges or universities. In addition the organisms involved are very small, yet highly complex and difficult to work with from a technical point of view. Furthermore, their life medium is the soil, an environment offering difficulties and complexities not found elsewhere. Finally, nematology, by nature a part of invertebrate zoology, requires, in its application to crop production, a knowledge of the principles of parasitology, plant pathology, soil science, and agronomy as well; this further complicates its study.

It should be mentioned that the Division of Nematology and a newly established unit at the College of Agriculture and the Agricultural Experiment Station of the University of California, are still the only agencies in this country dealing exclusively with these problems. The services of the Division of Nematology are required by Federal, State, and private agencies, individual growers, manufacturers of nematocides, manufacturers of equipment to apply nematocides or otherwise combat nematodes, and by others interested in related problems. The extent of these services may be measured by the amount of informative correspondence which annually numbers far over 1000 items, -- the bulk of them referring to control measures for plant nematodes.

Special mention should be made of the fact that the project includes services to regulatory agencies. Large numbers of nematodes are carried and distributed with plant material of any kind, such as food crops or nursery stock, and in soil and plant residues adhering to implements and conveyances. Certain plant nematode pests are the subject of special quarantines. The present project is to implement such quarantines and regulations and to help in their enforcement through identification of specimens found on imported plant material and other similar services.

As a project having primarily to do with crop protection against disease or otherwise noxious agents, the work program is subject to sudden changes. Unpredictable pest outbreaks and disease emergencies continually interfere in the pursuit of planned work and make the project in its phases highly changeable.

It is unfortunate that the greatest portion of our information on occurrence and distribution of plant nematodes is based on sample material submitted for examination and not on material collected methodically and according to plan. Thus our knowledge of plant nematodes is founded to a large extent on an accumulation of facts gathered by chance observations.

THE ROLE OF NEMATODES IN THE SOIL MAY WELL BE COMPARED TO THAT PLAYED BY INSECTS ABOVE THE SOIL

The annual loss to crop production caused by plant nematodes in this country, directly and indirectly, is estimated at between four and five hundred million dollars. This loss is primarily one of reduction in yield, but also includes indirect losses caused by the fact that nematode pests of plants frequently force the grower to rotations permitting cash crops only in periods of three or more years.

An estimate of the dollar value of the benefit nematodes cause by controlling noxious insects, slugs, and other organisms is not possible on the basis of available information.

The following table gives a breakdown of the project into its elements.

I. Nematodes as related to crop production and plant growth.
   A. Nematodes in their relation to plants.
      1. Nematodes as parasites of plants.
      2. Nematodes as carriers, distributors, and vectors of diseases of plants (bacteria, fungi, (?) viruses).
      3. Nematodes as secondary invaders of plants, i.e., following other primary disease agents; or taking advantage of weakened conditions due to other causes; or as part of a disease complex.
      4. Nematodes as controlling factors of plant pests: predatory forms, parasites of noxious insects, slugs, and other invertebrates.
      5. The enemies and diseases of nematodes.
   B. Nematodes in their relationship to the soil.
      1. Nematodes as members of the life association in the soil.
      2. Nematodes as related to the physical and chemical properties of the soil.
      3. Soil sterilization, soil disinfestation, and other soil treatments as related to nematodes.

II. Nematodes otherwise significant to the activities of man. (With exclusion of problems related to the parasites of man and other vertebrates.)

THE ELEMENTS OF THE PROJECT

1. NEMATODES AS PARASITES OF PLANTS: This is the principal subject of the present project. It is a problem of direct practical significance and it is for this reason that the project as a whole was initiated.

Wrong Approach to the Problem -- Early efforts in the study of these plant parasitic nematodes were completely over-shadowed by the search for control means. At least 90 percent of the literature on plant nematodes is written wholly from the viewpoint of control. The authors of the majority of papers of this considerable amount of literature never made a detailed study of the organisms involved nor did they have a basic knowledge of nematodes in general, of their structure, physiology, bionomics, classification, etc. This overemphasis on control had another unfortunate result: the repetition of the same or extremely similar tests and types of investigations, frequently with only a geographical or host variant. It was research lacking the basic tools.

Misconceptions That Caused Delay -- Because fungus and bacterial diseases are characterized by a quick and often killing action, it was long thought that plant infecting nematodes would present a similar disease picture. Plant parasitic nematodes, however, appear to live with their hosts in a high degree of balanced relationship. In other words, they try to live with their host plant, not to exterminate it. Their disease effect frequently is only that of reduced growth, reduced yield, or slow decline. They are a debilitation factor, a drag on crop production. This has tended to general underestimation of the pathological and economic significance of these pests.

Nematodes, with certain exceptions, are migratory disease agents. Parasitic forms need living host tissues to feed on. Frequently decay sets in where they have attacked and they are then forced to migrate to healthy tissues. Subsequent search of the necrotic tissues for pathogenic nematodes shows them absent or at best occurring in only small numbers. The wrong conclusion is then made, -- that the observed necrosis is not related to nematodes.

Disregard of the presence of plant-infecting nematodes in the soil has been the cause of failures in fertilizer tests, cover crop studies, and other experimental work. The interference of these pests with plant growth and yield thus has been the unsuspected source of confusing, and even of false experimental results.

What Has Been Done -- Today several hundred species of nematodes are known to parasitize plants. Of these some twenty are considered major crop pests. Certain of these pests have been the subject of more or less extensive studies, e.g. the root-knot nematode, the various bulb and stem nematodes (including the potato rot nematode), the golden nematode of potatoes, the sugar beet nematode, the nematodes causing spring dwarf and summer dwarf of strawberry plants, the nematode causing dieback in lilies, the chrysanthemum foliar nematode, the begonia nematode, the citrus nematode, the coconut palm nematode, various types of meadow nematodes, various seed-gall-forming nematodes, and many others. The root-knot nematodes are still considered the worst of these pests. Records are on hand reporting their occurrence in all but three States (South Dakota, Montana, and Rhode Island) of the continental United States. Since the species of this genus may cause specific symptoms such as swellings, knots, or galls on roots, they are the most easily recognized plant nematode pests and, partially for this reason, the best known and most intensively studied. Considered as among the worst agricultural pests the world over, their wide distribution and their significance as limiting factors in crop production are still greatly underestimated, even in our country.

Research on the root-knot nematodes has been more comprehensive than on any other plant nematode pest. Their life histories on certain hosts and also in regions of distinctly different climatic conditions, have been studied; their pathological effect on the hosts is to some degree known. Host strains and races have been found to exist. The phenomena of susceptibility, tolerance, resistance and immunity have been investigated, as well as modes of spread and distribution. Chemo- and hydrotherapeutic treatments for the cure of infected plants have been developed and tested, and, for the treatment of some hosts, found practical. Sanitation measures have been worked out and are today widely applied. Cultural control methods such as bare fallow, growing of trap crops, the use of immune and resistant cover crops, and the application of desiccation have been developed and evaluated by field tests. Control by crop rotation has been widely studied, taking into account regional and locational cropping methods and crop possibilities. Soil disinfestation has been the subject of special efforts. Treatments with heat (dry and moist) and chemicals have been tested. Liquid soil fumigants of volatile character have been found most promising in the control of these pests. Application methods adapted to a variety of crops, and regional and local conditions have been studied.

A few examples of accomplishments may be mentioned:

a. The fact was established that the roots, particularly the root tips, of certain so-called root-knot resistant or immune plants were invaded by large numbers of larvae of this nematode, but that these larvae were unable to grow in these roots and finally perished. Thus certain resistant or immune plants, e.g. Crotalaria spectabilis and marigolds, not only reduce a root-knot nematode infestation by starvation but actually trap and annihilate the nematode.

b. Field tests in a peach tree orchard demonstrated the possibility of a practical application of this remarkable host-parasite relationship. Trees of orchard plots with Crotalaria spectabilis as cover crop, during a period of six years, constantly yielded 6 to 12 times as many peaches as trees from plots with a susceptible cover crop. Trees of plots with a regular trap crop or with clean fallow gave yields constantly about halfway between the mentioned extremes.

c. The fact has been established that the root-knot nematode as conceived earlier represents a group of species each with different host range and reactions to climatic and other factors. It was shown by experiments, that, e.g. a southern species infecting potatoes in Florida and producing large protuberances on the potatoes does not withstand the rigors of winter here in Beltsville, Maryland; entirely different symptoms are produced on potato tubers by other species of root-knot nematodes. There are crops resistant to one species but not to others.

d. Establishment of the fact that there are plants highly susceptible to root-knot nematodes when young, but resistant when older (example: the tung tree).

e. It was shown that certain plants may be cured of a root-knot nematode infection by a hot water-formalin bath (e.g. peonies, tuberoses, black locusts), while others are not tolerant to such a bath (e.g. roses).

These and similar studies on root-knot nematodes were to a lesser degree duplicated on other nematode plant pests. As examples, there may be mentioned broad cooperative work on the golden nematode of potatoes, a pest discovered on Long Island, New York in 1941; investigations on the potato rot nematode occurring near Aberdeen, Idaho; studies on the nematode causing dieback in Easter lilies; investigations on nematode seed galls in Astoria bentgrass, in Chewings fescue, and other grasses; work with the narcissus bulb and the iris bulb nematode and the development in these instances of curative hot water-formalin treatments; studies on adaptation of these treatments to other plant nematodes and other hosts; work with meadow nematodes which attack a variety of host plants but particularly boxwood, potatoes, tobacco, olive trees, fig trees, and citrus; investigations on ring nematodes, on spiral nematodes, on the classification and identification of the cyst forming heteroderas; work on nematodes causing decline in mushroom crops; studies on nematodes causing "stubby" roots; investigations on the citrus nematode and many other similar problems.

2. NEMATODES AS CARRIERS, DISTRIBUTORS, AND VECTORS OF DISEASES OF PLANTS: A few authors have called attention to the fact that nematodes are carriers and vectors of other organisms. Little has been published regarding this matter. Extensive notes based on observations are in our files, but experimental work concerning this subject is almost completely lacking. The problem deserves consideration.

Nematodes, including plant parasitic types as well as others of the soil, have for some years been suspected to be vectors of so-called soil-borne viruses. This problem is at present being investigated in an exploratory way. Most significant is the carrier relationship between nematodes and bacteria. The large ecological group of so-called saprophytic and saprozoic nematodes clearly plays a most important role as distributors of bacteria. These latter may be carried attached to the surface of the body or more frequently in the intestinal tract of the nematodes. Less often fungus spores are distributed similarly.

3. NEMATODES AS SECONDARY INVADERS OF PLANTS OR OTHERWISE AS PART OF A DISEASE COMPLEX: Observations indicate that plants weakened by the attacks of other organisms or by climatic and similar causes are particularly attractive for nematodes. In these instances certain nematodes not considered parasites or pathogens of plants are observed as invaders. Planned research in this field is entirely lacking. It appears that not infrequently these secondary invaders are of importance, in preventing the recovery of a plant from the primary invader or disease cause, or in contributing materially to a final and rapid breakdown. There are many other phases of this problem and it appears that plant pathology eventually will have to approach these complex disease problems on a broad cooperative basis.

4. NEMATODES AS A CONTROLLING FACTOR OF PLANT PESTS: This problem relates to the question of how nature balances and controls nematode pests of plants. The known facts are as follows: There exist predatory nematodes which feed on other nematodes, particularly on those that attack plants. Evidence of this has been established by observations of actual predatory attacks, by a study of intestinal contents of certain predators and also by experimental tests. To what extent, however, natural control is thus established is not known. Attempts to colonize predatory types, such as certain mononchs, have not given sizeable results.

Nematodes, however, are notably parasites, and therefore a controlling factor, of such plant pests as noxious insects and slugs. Past work of an experimental character established the fact that the Mermithids, a large group of insect-parasitic nematodes, are a significant factor in a natural control of grasshoppers; where these Mermithids find desirable climatic conditions grasshopper outbreaks do not occur.

Another group of nematodes, the neoaplectanas, are very efficient controlling agents for soil insects, particularly the grub stages of the Japanese beetle, June beetle, and the white fringed beetle.

5. THE ENEMIES AND DISEASES OF NEMATODES: Enemies of nematodes are:

a. Mites, which have been observed feeding on agglomerations of specimens of the bulb and stem nematode. Such agglomerations, often containing thousands of larvae and called "nematode curds" or "nematode wool," have been seen completely consumed by mites. Similarly, egg masses and adult females of the root-knot nematode have been observed eaten up by mites.

b. On Long Island, New York, observations made in connection with the golden nematode of potatoes point to the possibility that small snails devour the cyst stage of this pest.

c. Tardigrades or bear animalcules have been seen feeding on nematodes.

d. Fungi-trapping and -catching nematodes were described by W. Zopf as early as 1888 and since then have been investigated by various authors. They appear to be one of nature's most effective control agents of nematodes in the soil.

e. Nematodes have their diseases; of these those caused by fungi, bacteria, and sporozoa appear to be the most important ones.

6. NEMATODES AS MEMBERS OF THE LIFE ASSOCIATION IN THE SOIL: The fact has already been mentioned that nematodes are extremely numerous in all soils having plant growth. Recent work in Europe demonstrated that there this group of organisms accounts for 99 percent of all the metazoans in the soil. Data on this matter are almost completely lacking for the soils in the United States. Recent counts in Switzerland showed the presence of from 2 to 18 million nematodes per square meter in the top 15 centimeters (about 6 inches) of cultivated and pasture land.

Soil science cannot afford to further ignore this component of soil life. It would appear that our present day conception of the biotic complex in the soil is at least largely incomplete if not erroneous through the one-sided consideration of only earthworms, bacteria, fungi, and noxious insects. The interrelations between these various components are also largely unknown.

7. NEMATODES AS RELATED TO THE PHYSICAL AND CHEMICAL PROPERTIES OF THE SOIL: Light sandy soils are preferred by certain plant parasitic types (root-knot nematodes). How far this preference applies to other forms is not known. It has been demonstrated, however, that certain nematodes are specific to muck soil, to peaty soils, to leafmold, etc. It is thought that additional information, particularly if based on planned and experimental work, might furnish valuable facts to be used in rotation schemes and in cropping methods. The significance of nematodes as a factor in breaking down organic material in the soil is another phase that has been overlooked. Furthermore, to what degree and how are the millions and billions of nematodes in a given soil of significance for its air and gas economy?

8. SOIL STERILIZATION, SOIL DISINFESTATION, AND OTHER SOIL TREATMENTS FOR NEMATODE CONTROL: The most important procedure in the control of plant nematodes is their elimination from the soil. There are no soil treatments known at present, however, that are exclusively nematocidal. The various soil treatments that give efficacious nematode control also eliminate other soil organisms to a certain degree. This is most often an additional advantage, since as a whole the biotic complexes in our crop lands are crop-antagonistic. The problem of soil treatments is, therefore, only partly one of nematode control. It has also a fungicidal, algaecidal, bactericidal, and insecticidal phase and involves other soil organisms, soil chemistry, and soil physics. As a research subject it therefore requires cooperative work.

Complete soil sterilization is not practical, and in nematode control work is used only in experimental set-ups. Steam is a most effective agent against nematodes but is practical only in greenhouses, seed beds, and small field areas. It has the advantage of penetrating into cracks and roots, thus exterminating nematodes most effectively.

Soil disinfestation by means of chemicals has become the most promising method of eliminaing nematodes. Toxic gases are not satisfactory because their application involves too many difficulties. Solids have not given very good results, apparently because it is difficult to mix them evenly with the soil. Most outstanding progress has been made with volatile liquids, commonly called soil fumigants. Such materials were first tested some 80 years ago to cure "soil sickness" or "sugarbeet tiredness" of a soil infested with the sugar-beet nematode. The nematocidal action of carbon disulfide was discovered at that time and although many hundreds of chemicals have been tested since, it is still used as a soil fumigant. Its nematocidal action is good but its explosive features make it unfit for general use.

Trichloronitromethane (chloropicrin or tear gas) came into use after the first world war. It was the first chemical used in large scale field fumigation but proved economical with high priced crops only. Through the recent discovery of the nematocidal action of such compounds as dichloropropene and dichloropropane mixtures (Shell D-D, Dowfume N), as 1, 2 dibromoethane (ethylene dibromide, Dowfume W, Iscobrome D, Soilfume, Bromofume), as bromomethane (methyl bromide, Iscobrome 1, Dowfume G), large scale field fumigation has been made practical. Over 100,000 acres of crop land are annually treated for nematode and wireworm control in the United States. Marginal, infertile land has been brought back to full fertility through soil fumigation. Land so treated appears always to produce better growth of plants. The case of the greatest yield increase yet observed as a result of soil fumigation may be cited. It involves a planting of sweetpotatoes which were attacked by root-knot nematodes and wireworms. The yield on treated land was seventeen times that of the untreated. Double and triple yields as a result of soil fumigation are not uncommon.

To reduce costs, several short-cut methods of soil fumigation have been tested and proven economical. For example: the spot" treatment" in the case of widely spaced crops such as watermelons, the "planting site treatment" in the case of shrubs and trees (a circular area of 3 to 6 feet in diameter is fumigated), and the "row treatment" in cases of widely spaced row crops (only the row to be planted is treated). Protection of the roots of the young plant is thus established. These short-cut methods permit the formation of long feeder roots and thus give the plant an enormous initial advantage. Any later invasions by nematodes would have a far lesser disease effect, confirming an old grower's saying, "first roots, then shoots."

The problem of mechanically applying fumigants to the soil most effectively has also been attacked. Numerous machine and hand applicators of various types have been constructed and are constantly being improved; applicator attachments to tractors and plows are already in use, some of homemade construction being built of second-hand spare parts. Thus we have today some very efficacious nematocidal soil fumigants permitting a per acre treatment at a cost of from $20 to $70, and these fumigants are easy to handle and not dangerous. A beginning has therefore been made in control by practical means of the many underground pests, paralleling the much more advanced methods of spraying, dusting, and fumigating of the above-ground parts of our crops and plants. A wide field for research of significant practical possibilities has thus been opened.

Other practices aiming at an elimination of noxious nematodes include crop rotation. In this case the attempt is made to exterminate certain nematodes by depriving them of their host plant. The application of heavy mulches is claimed to reduce infestations of the root-knot nematodes. Mulches appear to promote natural enemies of these nematodes, particularly nematode-trapping fungi. Flooding of land over long periods also reduces a root-knot nematode population; exposure to the hot sun and desiccation have a similar effect. The satisfactory use of these and similar treatments depends largely on possibilities of local conditions.

WHAT IS TO BE DONE

The answer to this question requires first an identification of the goal to be reached. This goal is obviously the elimination of all inimical interferences by nematodes in crop and plant production. It appears that a final solution of the problem would involve the complete eradication of all noxious nematode types. Such a solution is not in sight, not even in the case of individual forms such as the golden nematode of potato. In this country, this pest occurs in a single and restricted area, and would therefore appear to offer a simple eradication problem. This, however, is not the case. The next best definition of our aim would be "to find and develop the best methods, treatments, and procedures to reduce to the lowest possible degree the noxious interference by, and to promote the beneficial action of, nematodes in crop and plant production." This goal is primarily an economic one, and an acceptable work program pertinent to the project must primarily consider urgent disease and pest control needs. Longtime broad fundamental research enters the program as a second subject and may be considered after the primary economic needs are satisfied. Proper work planning should carefully evaluate the significance of each in any single program item. In this connection it is of interest to mention that during the past years the requests for urgent control of plant nematode pests have steadily increased so that less and less time could be devoted to fundamental problems. This, possibly, is due to two reasons: first, growers and investigators are becoming more familiar with plant-nematode pests;

and second, plant-nematode pests are rapidly and extensively distributed through human activities. It has already been emphasized that any work program set up in a project dealing with diseases and pests of the present type is variable in character and subject to unforeseen changes and delays, since pest outbreaks often present an emergency.

In a work program covering the present project, therefore, two main phases must be considered:

1. The existent pest and disease situation with which we are confronted, to be taken care of with the known control means.
2. The promotion of basic knowledge on a broad scale to better implement the handling and control of nematodes for the advancement of crop and plant production.

In the first phase primary importance should be given the proper identification of nematode pests of plants, the gathering of information on their occurrence and distribution and the evaluation of their significance. This is to be supplemented with dissemination of information on the subject and with the formulation of control recommendations.

Considering the specialized character of the subject matter and its inherent difficulties and complexities, it should be handled by trained specialists. Problems and pests of the present kind should be studied where they occur and control measures should be worked out on the basis of local conditions and cropping methods. This necessitates the establishment of a network of regional laboratories. Personnel at these laboratories work primarily on regional pest and disease problems in close cooperation with the growers and producers. Control work is a primary function. At present such laboratories are established at the following locations: Georgia Coastal Plain Experiment Station, Tifton, Georgia; Salt Lake City, Utah; Western Washington Experiment Station, Puyallup, Washington; Hicksville, Long Island, New York; Central Florida Experiment Station, Sanford, Florida; and Nematode Field Laboratory at Sacaton, Arizona. More are necessary to accomplish adequate service.

Phase two of the work program embraces the basic research. A diversity of subjects needs attention; preference is given to problems of immediate need from a pest control viewpoint. Examples of program items are: Work on soil fumigation, specifically a continued search for superior fumigants and improved application methods. Studies concerning the physiological action of these fumigants on the nematode organism and also their effect upon the soil and crops, and particularly the quality of food crops in conjunction with annual or other periodical fumigation. Basic work on specific pest problems such as the golden nematode of potatoes, the potato rot nematode, the root-knot nematodes, the sugar beet nematode, the citrus-nematode, seed-gall forming nematodes, spiral nematodes (Helicotylenchus), ring nematodes (Criconematidae), lance nematodes (Hoplolaimus), pin nematodes (Paratylenchus), spear nematodes (Dorylaimus), and numerous other types. Meadow nematodes (forms of the genus Pratylenchus) are increasingly recognized as extremely serious root parasites and appear to be of significance in various hitherto obscure diseases of ornamentals and crops, particularly the slow decline and dieback observed in certain orchards. These forms are little known; basic information concerning their structure and bionomics is badly needed.

THE UTILITARIAN ASPECT OF PLANT NEMATOLOGY RESEARCH

Since the present project is carried on with public funds a few remarks on the utilitarian aspect of this research appear appropriate. Annual appropriations are the investment, the dividends consist obviously in yield increases through control of plant nematode pests. However, this would be a rather incomplete calculation of the returns from the investment. It is evident that research under the present project produces profits not restricted to crop gains, but that other human activities and aims also benefit. Chemical industries and engineering, e.g., are involved through the manufacture, promotion, and application of soil fumigants. It is estimated that the present annual value of soil fumigants manufactured for nematode control amounts to at least $5,000,000. Machines and apparatus for the application of these fumigants also have to be considered, and likewise the experts that handle and promote this type of specialized work. Even the pursuit of certain hobbies may be mentioned in this connection, as e.g., the artificial production of the nametode (Panagrellus) on yeast cultures for fish food. Of more significance is the growing of house plants, many of which, such as the African violet (Saintpaulia), present specific nematode problems. Cut flower production and the whole nursery industry certainly benefit from the present project through additional income estimated several million dollars. Repeatedly, success of such an enterprise has depended on nematode control as, for instance, in the case of a war veteran who specialized in the production of tuberoses. Inroads by nematodes threatened complete failure which eventually was avoided through work under the present project.

Another example is furnished in the production of narcissus bulbs and flowers. The narcissus bulb nematode at the time of the first world war threatened complete destruction of commercial narcissus plantings. Research has enabled the industry to control this nematode and to live with it. A related nematode pest, the iris bulb nematode, during recent years threatened the production of bulbous irises in the Pacific Northwest. Work under the present project has re-established full production and is estimated to save the growers annually about $200,000. These last two examples further demonstrate another utilitarian phase of the present project, i.e., the promotion of home production versus foreign production and imports.

It should also be pointed out that with the growth of our knowledge of plant and soil nematodes, utilitarian objectives are more easily accomplished. As an example the discovery of a spawn-destroying nematode in mushroom beds may be mentioned. The identification of this nematode suggested immediately the pattern of control methods to be tested. Thus, previous experience with related nematode types brought about a cumulative utilitarian effect.

Concerning pest problems of recognized magnitude such as that of the root-knot nematodes, which is not only nation-wide but global, the annual savings resulting from work under the present project are estimated at millions of dollars for this country alone.

In the control of the sugar-beet nematode, a pest that in the early days of the beet sugar industry seriously threatened it, the annual savings are estamated at several hundred thousand dollars.

Finally, mention should be made of the fact that scientific work in other fields also benefits from progress of the present project. Particular reference is made to experimental studies on soils, specifically on fertilizer applications, also to tests of the plant breeder. Proper consideration of the factor "nematodes" in any soil used for such experiments may condition success or failure of such experiments.

Thus it is evident that benefits from the present research are quite diverse and that the project not only consumes tax money but also produces taxable income.

DIVISION OF NEMATOLOGY INVESTIGATIONS, BUREAU OF PLANT INDUSTRY, SOILS, AND AGRICULTURAL ENGINEERING

THE PLACE OF THE PLANT DISEASE SURVEY IN PLANT PATHOLOGICAL INVESTIGATION

Paul R. Miller

The Plant Disease Survey, for many persons, is practically synonymous with the Plant Disease Reporter, and more recently with the Warning Service. These most conspicuous and widespread services tend to obscure the Survey's own original contributions to plant pathological knowledge. The Reporter and the Warning Service are very obviously necessary to the proper performance of the Survey's best-known functions. The primary importance of "survey" research to certain kinds of problems is perhaps less evident, but it is no less closely connected with Survey objectives. The following account is designed to bring out the relation of these two aspects of the Survey work to each other and to plant pathology in general.

FEATURED SERVICES OF THE SURVEY

First place among the contributions of the Survey to plant pathology must be given to the Plant Disease Reporter. We must admit that we are proud of the Reporter and always give it right-of-way in our work. Best-known and longest established of the Survey's informational services, it was founded, as the Plant Disease Bulletin, in the first year of the Survey and has continued ever since, receiving its present name in 1923 (with volume 7). In its 34 years (1950, volume 34) the nature of its contents has changed considerably to correspond with plant pathological needs, interests, theories, and knowledge. In response to demand for a more permanent format the method of publication was changed from the original mimeographing to multilithing beginning with this year. This change has increased the usefulness, durability, and, not least important, the attractiveness of the Reporter immeasurably.

Of course the Survey cannot claim all the credit for the Reporter, since its contributors are responsible for the contents that make it so useful. Its greatest value is that it makes possible the prompt reporting of results and discoveries while they are still news, with detail enough for full understanding but without necessity for the thoroughness demanded by a complete presentation, which indeed should receive more formal publication.

The Supplements are an adjunct to the Reporter, for long articles or for material that is most effective when presented as a unit. Subjects of the Supplements are too numerous to list; some of them are quarantines, State lists of disease occurrence, diseases in foreign countries, market diseases, a series on cereal rust epidemiology and importance in the 1930's, the Survey's annual summaries of plant disease occurrence and the crop loss estimates, summaries of the Warning Service, forecasting, the summaries of results with new fungicides that were of use to both pathologists and the fungicide industry. Most recent are this series on plant pathological investigation, and Dr. K. Starr Chester's pioneer work on loss appraisal (7).

Between the earlier "Check List of Plant Diseases in the United States", issued in 1926 (1) and the new "Index" currently being published (40), 14 years have gone by. In the interim, plant pathologists have greatly increased their knowledge about occurrence and cause of plant diseases, but so have plant diseases increased in number and distribution.

The Warning Service was established recently as a logical outgrowth of the Survey's information function. It will be discussed in its chronological setting.

Of the Survey's numerous other informational tasks, only one need be mentioned: a monthly article on plant disease news compiled for publication in a chemical trade journal from the contents of the Reporter.

THE SURVEY'S CONTRIBUTIONS TO PLANT PATHOLOGICAL KNOWLEDGE

In a discussion of Survey work, it soon becomes evident that "Plant Disease Survey", as an organization, really has two easily distinguished meanings. One is general; it includes all the collaborators and other cooperators of the Survey. The other "Survey" is specifically the small official Survey staff.

A major part of Survey accomplishment is due to the inclusive organization. Not the least of its contributions, although mostly rather taken for granted, is the fundamental information on plant disease occurrence and importance acquired since the Survey was founded.

One method of adding to knowledge is to compile known facts in such a way that significant features are brought out clearly. Much of the Survey's contribution is of this nature -- always cooperative, of course. Typical examples are the crop disease hazard survey (32), the recent report on effects of losses on agricultural industries and on farm life (41), and the soil infestation survey (21). In all of these the information already existed but in separate isolated pieces; bringing it together gave it meaning and emphasis.

The reports on the results of the warning service (22, 24, 28) are further illustrations of this category. Each analyzes all the information obtained during the season; while the series is an outstanding contribution to the epidemiology of the diseases concerned.

These and other accomplishments of the inclusive Survey (we might add this series on plant pathological investigation in this country) are important; they give spatial and temporal perspective to plant disease study.

In its restricted sense, the Survey has taken its part in original investigation of plant pathological problems. N. E. Stevens (33) has stated the place of survey work and survey methods (not necessarily "Survey" with a capital "S") in research. His discussion emphasizes the generally undervalued role of observation. Research implications of the results of the Emergency Plant Disease Prevention program have been reported by ourselves (19, 27) and by others (5, 8). The Survey is currently responsible for various research programs under the Crop Plant Disease Forecasting Project, which will be described briefly in a later section.

Many of the Survey's special studies are mentioned briefly in their various chronological settings. Among them, two are of such different types, serving such diverse purposes, but each so consistent with Survey objectives and so characteristic of Survey investigation -- indeed they could only have been accomplished by survey methods regardless of who performed the actual work -- that we report them in some detail. The first was a pioneering venture and its achievements are still unique. The other is an illustration of the necessity for survey aid in a widespread disease control problem.

Parenthetically, we might remark that Survey investigation is mostly preliminary to further work by others, and often enough the starting point is overlooked in the final result.

THE KNOXVILLE MARKET AND KITCHEN DISEASE SURVEY: Although diseases affecting harvested crops at shipping points, in transit, at destination, and in storage, have been the subject of much study, very little is known about losses suffered by distributors and consumers. The Knoxville market survey in 1934 and 1935 was planned in cooperation with the University of Tennessee, as a beginning toward obtaining some adequate information as to the actual extent of such losses. It involved the determination of the origin, kind, and amount of plant food products that were brought into Knoxville, how they were shipped, where they were delivered, their condition on unloading, length of time between unloading and receipt by wholesalers and between wholesalers and retailers, type of handling received in all these stages, and the causes of decays and blemishes.

Carefully planned advance publicity through radio talks and newspaper writeups explained the reasons for the survey. The amount and quality of the cooperation obtained in later personal visits to distributors and homes was evidence of active interest in this subject.

Cooperators, both distributors and consumers, were furnished forms on which to keep records of fresh fruits and vegetables bought and of the amount discarded because of spoiling. Colored photographs of diseased fruits and vegetables (issued by the Bureau of Agricultural Economics and the Bureau of Plant Industry) increased distributors' understanding of the survey, and it was emphasized that their own records of such losses constituted a part of their profit and loss inventories. Consumers were given a chart with pictures and descriptions of some of the most common market diseases and a diagrammatic explanation of plant disease attack. Causes and extent of loss were checked in periodic visits by the investigators.

Procedure and results of this first comprehensive city-wide market disease survey were reported in Supplement 88 (14). Perhaps not the least important result was the understanding that cooperators obtained as to the nature of spoiling and the methods of handling needed to reduce losses.

COTTON SEEDLING DISEASE AND BOLL ROT SURVEY: The essential role of field information in the solution of some kinds of disease control problems is illustrated by the cotton seedling disease and boll rot survey conducted during the four-year period 1938 to 1941 by the Plant Disease Survey in cooperation with the Division of Cotton and Other Fiber Crops and Diseases.

Chemical seed treatment was effective in the control of certain seedling diseases, but much waste accompanied its use because the identity, distribution, relative importance, and epidemiology of the organisms involved, as well as their possible connection with organisms associated with boll rots, were known only to a limited extent. The only way to acquire this information was through a correlated regional survey throughout the cotton belt from the Atlantic Coast to Texas and Oklahoma, including not only field observation but laboratory and field study as well.

Means employed included counts and collection of over 2,000 samples taken in 14 States in numerous fields, laboratory identification of organisms associated with diseased seedlings and infected bolls, study of plants grown from infested seed at different locations under different conditions, determination of sporeloads on the seed, and investigation of the possibility of seed contamination during the ginning process. Entrance of this country into World War II prevented continuance of the survey, but at the same time it made even the foreshortened results all the more important because of the more definite basis for control of seedling diseases and consequent reduction in waste of effort and material.

Results included: 1 -- The anthracnose fungus, Glomerella gossypii, which was thought to have become a minor factor, was found, on the contrary, to be widespread throughout the Southeastern States. It was isolated from four-fifths of the seedling disease samples and two-thirds of the boll rot samples, and was by far the most frequently occurring pathogenic organism in both. 2 -- Discovery that anthracnose symptoms on affected bolls were entirely dissimilar to those described in classic earlier work on this disease explained the general non-recognition of its presence. The difference in symptoms probably followed the introduction of the boll-weevil and the consequent adoption of varieties with a more open type of growth, not conducive to the development of the earlier-known symptoms. Evidence was also obtained indicating that insect punctures and prior infection by Xanthomonas malvacearum favored infection by Glomerella, further confusing the symptoms. 3 -- Results of seed treatment had indicated that seed was the principal source of seedling infection, but the amount of seedling anthracnose infection determined during the survey was much larger than would be expected from the number of bolls observed to be infected with Glomerella. In specific investigation of this discrepancy it was determined that "trash", including broken parts of the cotton plant or debris picked with the seed cotton, may carry more spores than the seed. In the thorough mixing of the ginning process the seed is likely to become contaminated with the fungus, even though ginning removes most of the trash. The degree of seed contamination depended on that of the trash. Carry-over of contamination in ginning from one seed-cotton lot to the following lot was also demonstrated. Thus it was concluded that contamination of the seed in ginning was responsible for much of the damping-off due to Glomerella infection. 4 -- Glomerella was abundant in the southeastern part of the Cotton Belt, but was practically absent west of eastern Texas and Oklahoma. Evidence obtained during the survey indicated that this distribution depended on climatic conditions, although no simple correlation could be determined. Besides the geographical distribution itself, the evidence included observed variation in amount of anthracnose infection on seedlings and bolls corresponding to variation in weather between seasons, studies on the relative degree of infection of seedlings grown from contaminated seed at different locations with diverse conditions, determinations of comparative spore loads on seed originating in different sections, and studies of progressive infection of the cotton plant from seedling to maturity. It was found that summer spread was largely saprophytic, infection taking place in any part of the plant, mostly through injured or moribund tissue which becomes more abundant as the plants mature. Infection advances or remains latent according to circumstances; under favorable moisture conditions, rapid spread in rotting tissue provides potential inoculum for boll infection. Evidence indicated that lack of summer rainfall is one of the factors in absence of the fungus on bolls and seed from Western regions. 5 -- The survey clarified the role of other organisms as well as of Glomerella in the causation of seedling disease and boll rot, explained discrepancies with results from seed treatment in different areas, and gave a solid basis for further research on control.

The results with Glomerella were somewhat unexpected at the beginning of the investigation and demonstrate clearly the role of surveys in defining the exact problems that must be faced. Complete results have been reported elsewhere (17, 25, 39).

OBJECTIVES AND HISTORY OF THE SURVEY

"The principal objects of the Survey broadly stated are: first, to collect information on plant diseases in the United States covering such topics as prevalence, geographical distribution, severity, etc., and second, to make this information immediately available to all persons interested, especially to those concerned with disease control." This brief statement, quoted from the first number of the Plant Disease Reporter (Plant Disease Bulletin as it was called for the first few years, vol. 1., no. 1, Aug. 15, 1917), is still an accurate summary of the Survey's functions.

The Plant Disease Survey was established as a separate unit of the Bureau of Plant Industry in 1917, during the first world war. The accompanying chart (Figure 1) gives a graphic record of its history. The chart shows very well the influence of emergencies on the demand for survey services: first is the first war, then the high peak of the second world war when the Survey administered the Emergency Plant Disease Prevention Program, finally the effect of the 1946 tomato late blight epidemic is manifested in the Forecasting Project under the Research and Marketing Act.

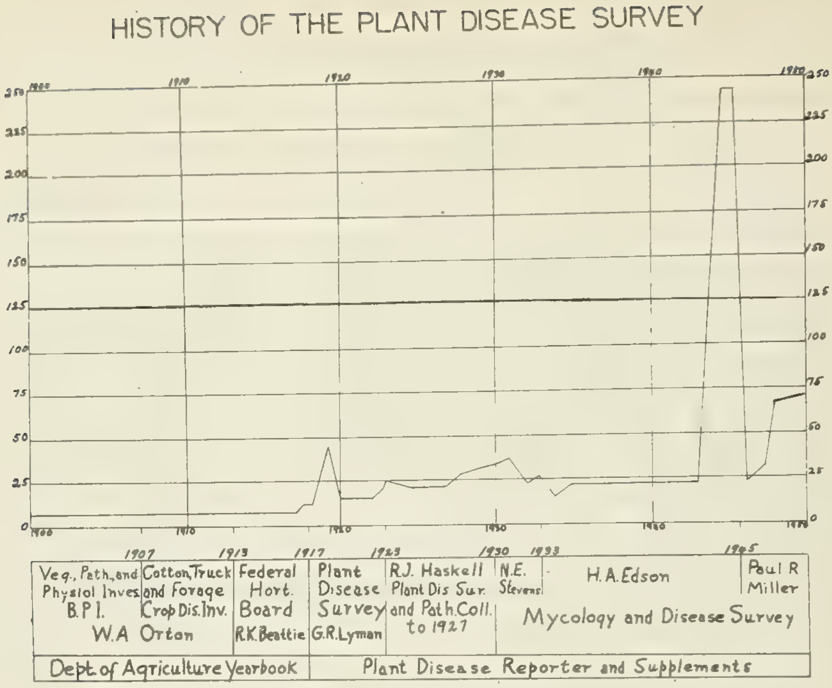

Figure 1. Chart indicating the personnel in charge, official source of publication, Divisional relation, and annual fluctuation in amount of appropriations of the Plant Disease Survey for the past half century. The line shows the amount of funds in thousands of dollars by increments of twenty-five.

A word about how the Survey operates will help in understanding the problems connected with maintaining the collection and recording of plant disease information. Figure 2 is a diagram of the Survey organization. Disregarding for the moment the broken lines, it is clear that the collaborators, who are State plant pathologists appointed to cooperate with the Survey in each State, form the mainstay of the reporting system. Except for brief periods or for special purposes, the Survey has always depended on voluntary reports. When the Survey was first established, practically all plant pathologists were personally and actively interested in its affairs, and the voluntary reporting system worked very well indeed. As time went on it became less productive, for various reasons cumulative in effect. The very increase in knowledge on occurrence, distribution, importance, etc., resulting largely from the Survey's own efforts, was responsible for a feeling that a saturation point had been reached, and that accumulation of further records would be useless. Pathologists' work became increasingly specialized and localized; correspondingly, interests became less comprehensive, chances of observation restricted, and time available for voluntary tasks scarcer. A series of drought years reduced occurrence of many plant diseases to a minimum, and although real understanding demands knowledge of absence or scarcity as well as of outbreaks, negative occurrence seems never to be very interesting. Outbreaks or emergencies of one kind or another arouse interest; ordinary occurrence or absence is apt to be slighted in reports. Finally, during the financial troubles of the 1930's, plant pathology in general felt the effects of the prevalent overproduction complex. Frequently it was said -- not by plant pathologists -- that plant diseases were useful rather than detrimental.

All of these factors, separately or together, influenced the effectiveness of the reporting system.

All voluntary systems have disadvantages, however, and we believe that the advantages have outweighed the drawbacks in the case of the Survey. At its best, the cooperative attitude of responsibility for the Survey has been a decided asset. I take this opportunity to acknowledge the Survey's indebtedness to its collaborators.

EARLY PHASE -- EVOLUTION OF SURVEY PROBLEMS: When the Survey was first established, under Dr. G. R. Lyman, distribution and importance of even some of the most common diseases was known only incompletely, and knowledge about plant disease occurrence in general was inadequate. One of the reasons for the Survey was the realization that this lack of knowledge about potentially important agricultural hazards might have serious consequences in war time.

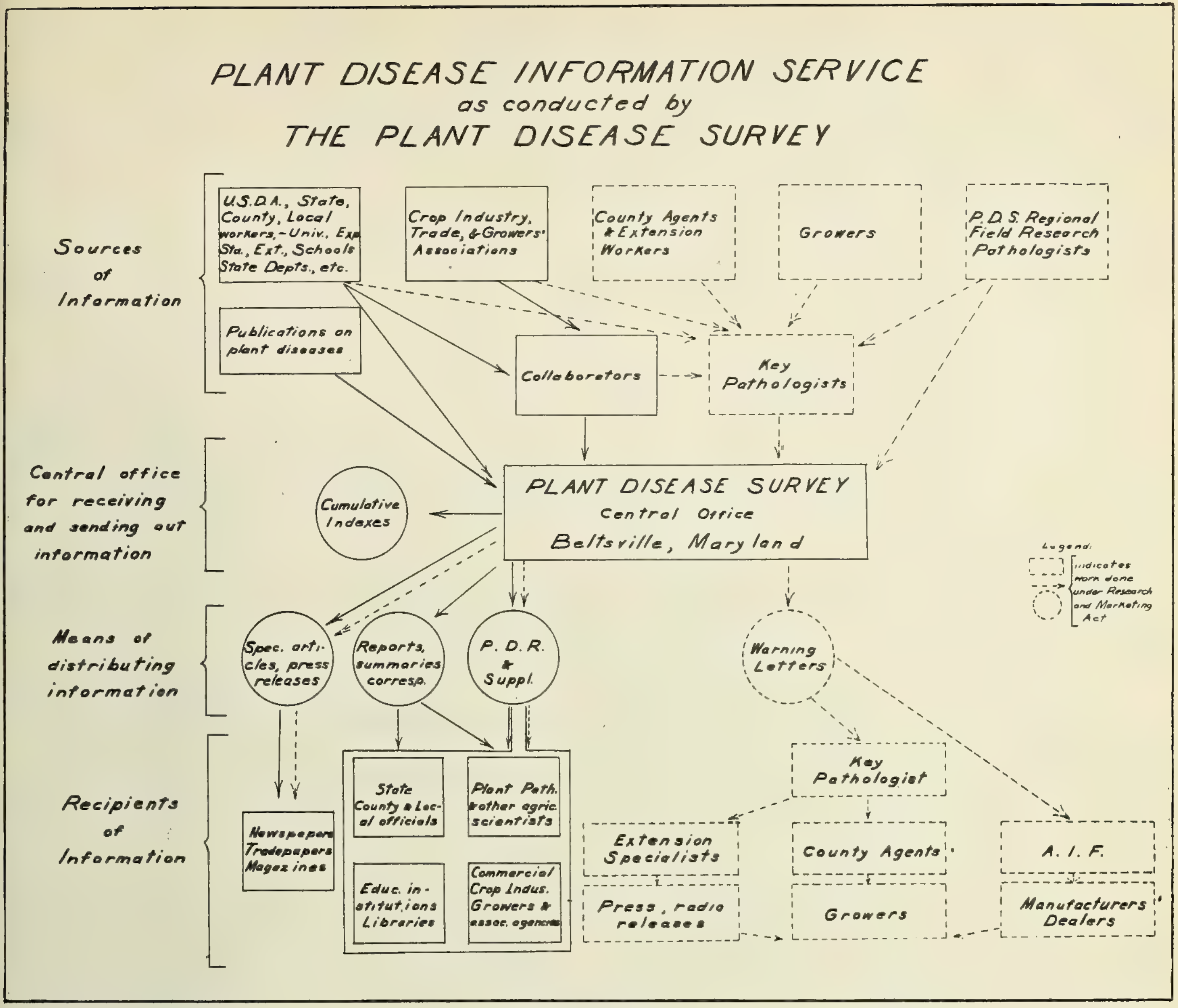
PLANT DISEASE INFORMATION SERVICE
as conducted by
THE PLANT DISEASE SURVEY
Sources of Information
U.S.D.A., State, County, Local workers,-Univ., Exp. Sta., Ext., Schools State Depts., etc.
Crop Industry, Trade, & Growers' Associations
County Agents & Extension Workers
Growers
P.D.S. Regional Field Research Pathologists
Publications on plant diseases
Collaborators
Key Pathologists
Central office for receiving and sending out information
Cumulative Indexes
PLANT DISEASE SURVEY
Central Office
Beltsville, Maryland
Legend:
indicates work done under Research and Marketing Act
Means of distributing information
Spec. articles, press releases
Reports, summaries corresp.
P. D. R. & Suppl.
Warning Letters
Recipients of Information
Newspapers Tradepapers Magazines
State County & Local officials
Plant Path. & other agric. scientists
Educ. institutions Libraries
Commercial Crop Indus. Growers & assoc. agencies
Key Pathologist
Extension Specialists
County Agents
A. I. F.
Press, radio releases
Growers
Manufacturers Dealers

Figure 2

The Survey's first efforts were devoted to remedying this situation.

Regular frequent current reports on disease development on major crops were sent in during the season by the Survey's collaborators and published promptly in the Reporter. Annual summaries of all available information from whatever source were compiled each year.

The collaborators constituted a "watch-service" -- so designated by Dr. Lyman -- to watch for and report immediately new diseases or other unusual or threatening occurrences.

Special surveys were made to find out definitely where certain important diseases occurred. For example, the potato wart disease (Synchytrium endobioticum) was newly discovered in this country; its existence here was a menace but just how widespread it had become was unknown. In cooperation with the Federal Horticultural Board, the Survey determined the very limited distribution of this disease so that intelligently planned measures could be taken against its further dissemination. The early volumes of the Reporter contain progress reports on many such surveys, some conducted by the Survey itself, some under other auspices, e.g., the 1919 cereal disease survey conducted by the Office of Cereal Investigations.

In this period also the annual Crop Loss Estimates were started. The reason was obvious: to obtain some adequate idea as to the intrinsic and relative importance of the diseases of major crops, so that plant pathologists would be able to direct their energies effectively and have a measure by which to judge the results of their work. So little was known about the real extent of damage from plant diseases that any attempt to state it in understandable terms necessarily involved investigation of this specific problem, and the estimates were both a result of need for such study and a starting point for further work. However, it became evident with time that many circumstances prevented the estimates from being or becoming as accurate in the strict sense as it was thought numerical expression should be, and certainly that they were far from being reliable enough for many of the uses to which they were put. Lack of knowledge about the connection between amount of disease and extent of damage was one factor; it could be corrected with study but in the meantime estimates were on an uncertain basis. Psychological bias has been discussed (18); conscious effort and objective criteria are needed to overcome it. Not the least factor was the changing situation already mentioned, in collaborators' interests and opportunities. In any event, the estimates, in this form, very likely had reached the point of diminishing returns before they were discontinued in 1939.

In justice to the estimates, however, we should say that some of them for which independent sources of comparison were available agreed in all essential features (35).

From the beginning until 1939 annual summaries on the incidence of plant diseases in the United States were compiled from the reports of Survey collaborators and other available sources. The usefulness of these summaries was generally acknowledged and the Survey gave them up with reluctance; reasons for their discontinuance are obvious from what has already been said.

The Crop Loss Estimates and the Annual Summaries are now source books for the history of plant diseases and of plant pathology in this country, for the period that they cover.

Toward the latter part of this early phase the Survey conducted comprehensive field studies in cooperation with selected States (2, 3, 4). A staff member devoted full time to identifying the diseases occurring on the crops grown in the State, determining their distribution and estimating the amount of loss they caused, as well as placing specimens of each in the Mycological Collections of the Bureau.

In view of the recent stress on the forecasting of plant diseases, especially late blight, not the least interesting although apparently forgotten activity of this early period is the watch service in Michigan, Wisconsin, and Minnesota reported in the following quotation (from *Plant Disease Reporter* (Bulletin) Vol. 2, No. 4, page 54, June 15, 1918):

"Conditions in the three States mentioned make the late blight problem a different one from that in the eastern and northeastern part of the country. Here outbreaks of *Phytophthora* are of less frequency than in the latter sections, but when an outbreak does occur the damage is enormous. For this reason spraying as a yearly proposition is not profitable. It is believed therefore that the best solution of the problem is to maintain an efficient watch service for the first occurrence of the disease."

Thus the logical connection of the Survey with plant disease forecasting was foreshadowed in the earliest times of its existence.

This early part of Survey history accumulated a much more satisfactory knowledge about the plant diseases that were present, where they occurred, how much damage they caused, how rapidly they spread, and, as far as could be determined or indicated from observation, the factors involved in spread and severity.

Although phases are clearly discernible in Survey history, there is no definite dividing point between them. The problems of one phase may carry over and endure for a while in the next and is a change in orientation that distinguishes each phase from its predecessor.

The dictionary definition of "survey", as far as it is pertinent to our Survey, is "1. to take a general or comprehensive view of. 2. to view in detail . . ." (American College Dictionary, Random House, 1947). In this early phase stress was on the general, or "comprehensive" view. This view continues throughout Survey history, but circumstances determine its prominence.

Even during this early phase, however, attitudes started shifting so that the second half of our Survey definition, the "detailed" view, became more and more the dominant one. With the background knowledge established, the need was greater for definite information on particular aspects. One response to this need was the surveys to determine the plant disease content of limited areas, as in various States. With the tobacco disease survey the change became marked enough to lead into a new phase just before Dr. R. J. Haskell left the Survey to become Extension Plant Pathologist for the U. S. Department of Agriculture.

Because of Dr. Haskell's strong belief in the value of detailed and systematic research and his ability to stimulate active cooperation on the part of the Survey collaborators the annual summaries and crop loss estimates reached their maximum completeness during this period.

SECOND PHASE -- FOCUSING: The concentration of Survey effort that had already become more and more evident in preceding years is the dominant characteristic of this phase. Two pressures determined its work: one was the demand for specific information, the other was the preeminence of economics in the thought of the time. At the beginning of this period Dr. Neil E. Stevens was in charge of the Survey. Characteristically, he understood how the possibilities of Survey investigation could best serve the current necessities.

The market disease survey already reported combined both economic viewpoint and specific inquiry (14). Another contribution to plant disease economics was the compilation of "plant disease hazards" also cited above (32), which called attention to the importance of plant diseases in agricultural industries, and gave unmistakable proof that plant pathologists should be consulted, along with other agricultural scientists, in agricultural planning, land utilization programs, and irrigation developments, so strongly emphasized at that time.

The intimate connection between Survey and forecasting was demonstrated again. The records on bacterial wilt of sweet corn (Pseudomonas stewarti) showed that occurrence fluctuated with temperatures of the preceding winter, and a simple but precise method of forecasting severity was worked out, depending on the sums of the average temperatures for the winter months. The method has been so reliable that with some modifications it is still in use wherever sweet corn is important and the disease is a factor (33, 34). A basis for predicting occurrence of tobacco blue mold (Peronospora tabacina) also resulted from the study of Survey records, which indicated that earliness of appearance, rapidity of spread, and potential severity were correlated with January temperatures in South Atlantic Coast States. Later warning service experience has confirmed the accuracy of this observation (15, 23).

Some other accomplishments of this period may be mentioned briefly. Surveys that delimited the distribution of the rust diseases (Gymnosporangium spp.) of apple explained some hitherto puzzling circumstances about their occurrence (12, 13, 16). Crop surveys gave background for research on and control of diseases of tobacco, sweetpotatoes, and peanuts; these were reported currently in the Plant Disease Reporter between 1933 and 1936. The cotton seedling disease and boll rot survey described in detail above (25) was cut short by the Second World War, which opened another phase of Survey work.

THIRD PHASE -- WORLD WAR II AND THE EMERGENCY PLANT DISEASE PREVENTION PROGRAM: The third phase was again an emergency period. The safety of crops was a prime consideration in national defense and the Emergency Plant Disease Prevention Program was set up to ensure it. A certain amount of misunderstanding and prejudice that the program had to cope with at first was overcome as its real purpose gradually became evident, although never explicitly stated. The primary objective was to prevent malicious damage by enemy action, which required secrecy and a staff devoted to the one end and large enough to accomplish it.

A project of such magnitude as this, with its inherent problems of acquiring an adequate staff so suddenly and of operating with no idea of the duration of the work, and especially its confidential nature, was exceedingly difficult to administer. Its successful prosecution should be attributed in large measure to Dr. H. A. Edson, who possesssed the combined advantages of his own unusual administrative ability and his long years of experience with personnel and Civil Service affairs.

Achievements of the fundamental defense task have never been divulged. Published results (19, 27) of the Program's activity were a by-product, nevertheless, they were of the greatest aid to agriculture during the War period and later. They showed that the ever-changing nature of plant disease occurrence soon makes our information out-of-date or even misleading without constant and widespread watchfulness. On the positive side they demonstrated conclusively how much help planned surveys by a competent professional staff do give to investigation of plant diseases. This was the only time that the Survey has had the advantage of a really adequate field staff.

Certain activities of the Emergency Plant Disease Prevention Program were among the direct forerunners of the Crop Plant Disease Forecasting Project and thus led into the present phase of Survey history. One was the "warning service" rendered by the Emergency Program reports on the appearance and progress of potato late blight during the unprecedented epidemic in Southern States in the 1943-44 season. Similarly, the outbreak of the aster yellows virus disease in carrot fields of the Texas Winter Garden region was watched carefully. A related service was the locating and reporting of incipient disease outbreaks to make sure that scarce chemical control materials reached the places where they were needed in time to do some good, as far as was possible during the war (27).

The fundamental result of the Emergency Plant Disease Prevention Program, of great importance to the Survey, and also, we believe, to plant pathological study in general, was to establish the fact that survey data are not an incidental feature of plant disease investigation, but constitute one of the essential parts, and should be planned for as carefully as experimental work.

NOW -- SERVICE PLUS RESEARCH: Although many strictly Survey problems are of research rank, original investigation by the Survey has hitherto been restricted in extent and scattered in subject. The essential characteristic of the present phase is the acknowledgment of the necessity for research by the Survey in the performance of its own tasks. This is shown in the research provisions of the Crop Plant Disease Forecasting Project set up originally in 1948 under the Research and Marketing Act (31).

The second distinguishing feature is the establishment of regional forecasting as an official function of the Survey. It had long been evident that wide-scale watchfulness was necessary for best control of certain diseases. While it is probably true that this knowledge would have led to an organized warning service sooner or later anyway, the tomato late blight epidemic of 1946 was such an emphatic demonstration that it crystallized demand for immediate establishment of a forecasting program. Moreover, plant pathologists recognized that merely a reporting service by itself would not be adequate for any but superficial results, and that research on epidemiology must accompany it; also, that both warning service and research should be on a regional scale.

Forerunners of the Forecasting Project may be enumerated briefly: the potato late blight warning service conducted by the Mississippi Valley Plant Pathologists' Committee during the war (11), the informal systems of current reporting on cucurbit downy mildew in the Atlantic Coast States (29) and on tobacco blue mold, the service of the Emergency Plant Disease Prevention Program in watching for appearance and development of plant diseases and reporting urgent need for fungicides, finally, the 1947 tomato late blight warning service.

This preliminary warning service in 1947 was the immediate response to the demand arising out the 1946 tomato late blight epidemic (26, 28). It was simply a warning service: the Survey received current reports on occurrence and accompanying circumstances from key pathologists in cooperating States and Canadian Provinces, assembled them into "warning letters", and relayed them promptly to the key pathologists, who in turn used them as basis for recommending the precautions that farmers should take against the disease. The practicality of this preliminary service was the decisive factor in the authorization of its successor, the Forecasting Project.

The present warning service operates in the same manner. Besides late blight (Phytophthora infestans) on both potato and tomato, it includes tobacco blue mold (Peronospora tabacina), and cucurbit downy mildew (Pseudoperonospora cubensis) (31).

The relation of the warning service to the Survey proper is shown in Figure 2, in which the broken lines represent the warning service, the solid lines the Survey. It is evident that both are dependent on the same type of cooperative reporting system.

Weather is so important in the development of these diseases that much study has been given to the usefulness of long-range weather forecasts, including those of private services and of the Weather Bureau. The 30-day forecasts of the latter have only recently become available; by arrangement with the Weather Bureau they are being sent to all key pathologists, who report, for the most part, that these forecasts increase the accuracy of their own disease predictions. This cooperation between Weather Bureau and warning service is the subject of Figure 3, adapted by the Weather Bureau itself for use on one of its daily weather maps (38).

Availability of fungicides and control equipment is another factor in control, and manufacturers of both are kept informed through their industry associations (Figure 2, 3). The annual summaries of the warning service give much attention to the success and extent of use of control measures; this analysis helps fungicide manufacturers to judge the efficiency of their own products.

The operation and basic features of the Forecasting Project's research program have been described elsewhere (31). At present it is concerned primarily with the epidemiology of late blight. Research topics include the separate and combined effects of meteorological factors, including microclimate; the existence, distribution, and characteristics of host and/or geographical strains of the organism; possibility, methods and routes of long-distance spread. In connection with this last phase a project involving the utilization of radioactive isotopes has been initiated. Preliminary reports on various aspects of this reaearch have been published (9, 10, 30, 36, 37).

In a way, except for its proved practicality, the warning service also is experimental, as far as criteria for basing predictions are concerned. Already, on the basis of existing knowledge, experience has increased the accuracy of the local forecasts. For the future, results from the research program, even though tentative and preliminary, will be applied to warning service use as soon as their usefulness for prediction is indicated. The accumulated records compiled in the warning letters and analyzed in the yearly summaries (22, 24, 28) will give invaluable background for interpretation and adjustment. These records, we consider, form a part of our research data obtainable in no other manner, and represent the equivalent of a region-wide laboratory experiment.

WHAT NEXT?

Development in the warning service indicates the definite likelihood of forecasting probability of disease occurrence for widespread regions, much as the Weather Bureau forecasts weather, instead of on a State or local basis, as now.

A more distant possibility closely connected with Survey objectives, perhaps not realizable in the near future but foreshadowed by pressure from increasing need, is research into methods of sampling and loss appraisal, leading toward a revival of loss estimates on a substantial basis

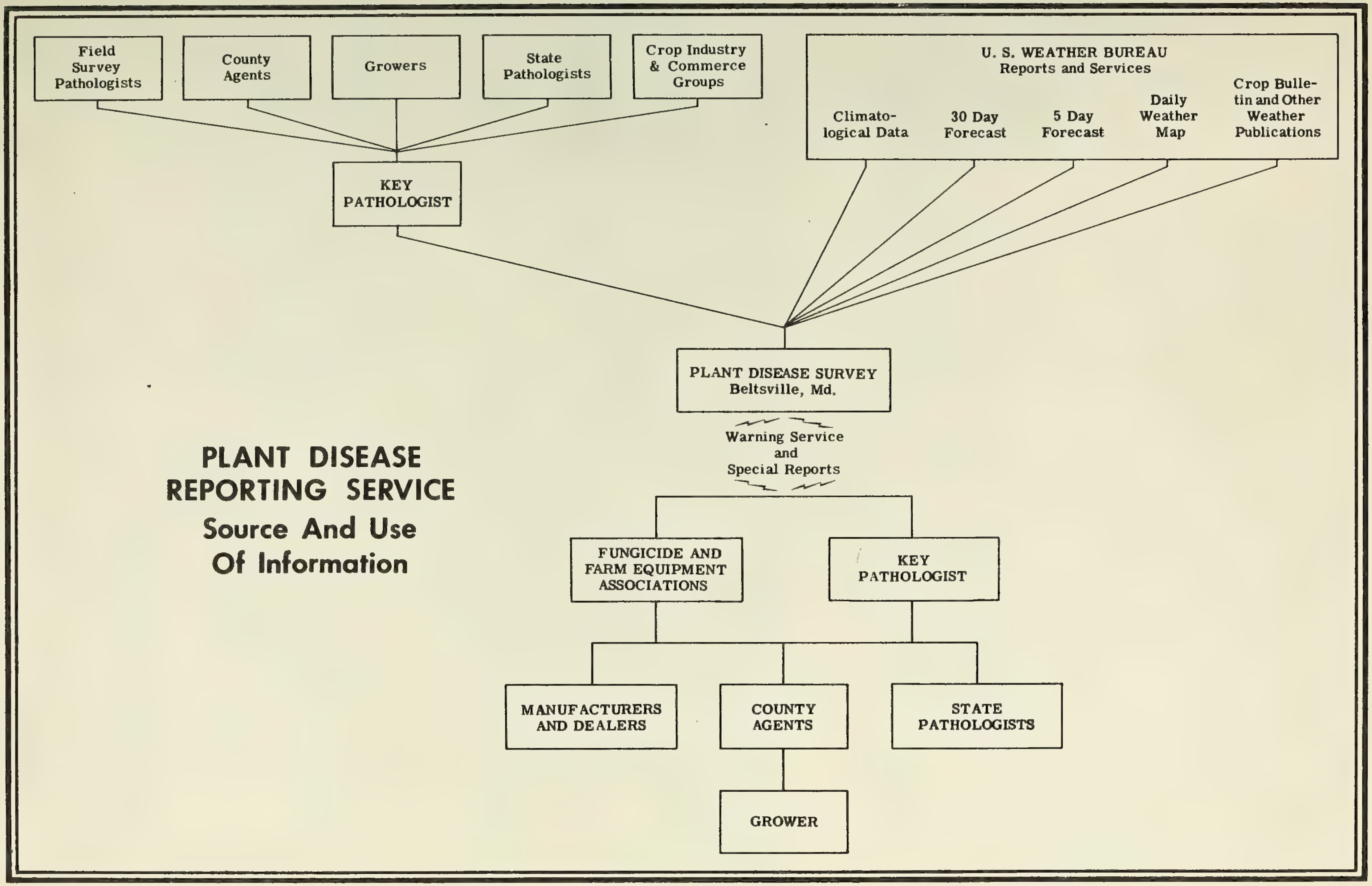
PLANT DISEASE REPORTING SERVICE
Source And Use Of Information
Field Survey Pathologists
County Agents
Growers
State Pathologists
Crop Industry & Commerce Groups
KEY PATHOLOGIST
U. S. WEATHER BUREAU Reports and Services
Climatological Data
30 Day Forecast
5 Day Forecast
Daily Weather Map
Crop Bulletin and Other Weather Publications
PLANT DISEASE SURVEY Beltsville, Md.
Warning Service and Special Reports
FUNGICIDE AND FARM EQUIPMENT ASSOCIATIONS
KEY PATHOLOGIST
MANUFACTURERS AND DEALERS
COUNTY AGENTS
STATE PATHOLOGISTS
GROWER

Figure 3

of experiment and observation.

Plant disease geography has so far received only limited attention from plant pathologists. We believe that there is sufficient foundation now for at least preliminary studies on this subject. The organization of plant disease knowledge that such studies would involve would certainly help to interpret much that is obscure or apparently contradictory in its present state. This is an important field of plant pathology, but of course it is one that requires cooperative effort.

These are not isolated, independent topics, since both loss appraisal and an adequately based science of plant disease geography will ultimately become necessary for progress in forecasting. Loss appraisal is also an adjunct to plant disease geography.

Both loss appraisal and forecasting are methods of testing our knowledge. Much as we may desire to have them absolutely reliable, there are times when immediate need calls for whatever guess can be formulated on tentative or incomplete information and to wait for accuracy would be worse than useless. Perhaps some such course as that outlined by Bode et al (6) should be included in the education of plant pathologists. I quote:

"Somewhere in the curriculum, . . . there should be a course in judging guessing, and the scientific method. This course is needed not only by the generalist, but by many other scientists. We have no way now to encourage or require a man to bring his education and intelligence to bear on estimation and prediction problems for which he has inadequate information. As a result, scientists often become stuffy and narrow in their views. To meet this need, we propose a course in educated, intelligent guessing. It would be principally a laboratory course, in which essentially impossible problems were put to the student, who would be required to supply answers and estimates of their trustworthiness, on the basis of the inadequate data given plus what he knows about the world. . . . . The main difficulty with this course would be finding an instructor equipped to teach it."

CONCLUSION

Elsewhere (20) I have said that the objectives of the Survey could be summed up thus: "to help plant pathologists make use of past experience with plant diseases, keep track of present problems, and anticipate future needs." This has been the aim of all Survey work, in all its aspects, throughout its history.

No acknowledgment could do justice to the planning that Dr. Lyman put into the Survey at the outset, which included all the functions that are logically a part of Survey work, nor to Dr. Haskell's genius for organization and cooperation that made the Survey's first phase so fruitful, nor to Dr. Stevens' original thinking that discovered such possibilities for Survey aid both during his tenure as head of the Survey, and afterward, nor the superior administration of Dr. Edson in spite of the difficulties faced, first in a time of "recession", and again in sudden expansion. The Survey is the result of their combined guidance.

I have already mentioned the role of our collaborators.

This discussion has stressed the "give-and-take" nature of Survey work. We hope for continued and increased cooperation from all plant pathologists.

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STATE QUARANTINES ON INTERSTATE MOVEMENT

W. A. McCubbin

INTRODUCTION

It is generally recognized that the objectives of State quarantine and regulatory activities do not differ materially from those in the Federal field. Pest species are the same for both; there is the same need for knowledge on life histories, behavior, methods of spread, and means of control; for each there must be research, survey, community effort, popular understanding, proper equipment, financial backing, and legislative support. Both agencies may at times aim to eradicate pests, or to control them, or prevent their spread to new areas. In many cases State and Federal interests are practically identical and a common cooperative plan of attack can be set up against a specific pest. Thus any difference between the two agencies in their quarantine work lies not so much in objectives and operational conditions as in the legal powers each has available, the manpower and equipment each is able to muster, and the practical limitations within which each must work.

The matter of respective legal powers deserves come elucidation. Based on Constitutional grants of power Federal authority is paramount in the field of interstate and foreign commerce but is limited to these fields. This would imply that where the Federal government has exercised its constitutional right to prohibit or regulate the movement of specified materials or products in interstate or foreign commerce as a measure of pest protection, any attempt by a State to promulgate prohibitions or set up regulations on such movement in either field would probably be declared unconstitutional by the courts. However, the State's retained powers are regarded as unimpaired by this separation of function. State legal authority derives from powers inherent in the original status of the State as a sovereign political entity; all such original powers not relinquished to the Federal Union by the Constitution are still retained by the State. These retained powers include the police power, the right of entry and inspection, control over storage or maintenance, and the destruction of property when necessary in the public interest. When these potential powers have been given reality by specific State legislative action they come into practical effect and are enforceable in the courts. It is evident that the State thus stands on a far broader legal basis than the Federal authority in the scope of its quarantine functions. For this reason a State is in a position to undertake many projects for which Federal legal power is lacking or is too limited. For this reason also most large-scale quarantine enterprises require a judicious combination of Federal and State action to deal effectively with all phases of a complex situation. Cooperation of this kind is a commonplace feature in the quarantine field. In such cases the Federal authority is used to regulate or control interstate movements of dangerous materials, and State authority takes care of similar movements within the State. In addition, however, field surveys, inspection on premises, treatments at source, holding requirements, the destruction of property, and all other phases of the common program not involving movement in interstate commerce must be carried out under State legal authority.

This sharply drawn line between Federal and State legal responsibilities and limitations might introduce an awkward and embarrassing cleavage in function. These are two features, however, which go far to overcome these hard-and-fast legal distinctions and thus permit a high degree of flexibility in actual practice. The first of these is a widely prevalent legal provision for State-Federal cooperation, whereby either party may assist the other in various ways without disturbing or weakening the legal relations on either side. For example, Federal personnel may report violations of State quarantines; State inspectors may be empowered to act as Federal agents and vice versa; loans or contributions of equipment and materials can be made back and forth; facilities and services of various kinds can be interchanged; and purse strings may be loosened at times to help out the other cooperator.[1] In these and other similar ways a common program can be carried out successfully despite the seemingly inflexible legal limitations mentioned above.

A second factor in the situation permits considerable freedom of State quarantine action in spite of the apparent legal limitations arising out of Constitutional division of powers between the Federal authority and the State. This is the right to impose interstate quarantines. Basically this function belongs to the Federal agency because of its Constitutional responsibilities in interstate commerce. Yet there are many pest situations which for technical, operational, financial, or administrative reasons can be met more adequately by State quarantine and regulatory measures than by Federal action. Consider, for example, the nursery inspection program established in practically every State. Individual nurseries in varying degrees normally distribute their products both within the State and to other States. While the Federal agency could properly undertake to regulate the interstate phase of such movement, the intrastate portion of it is outside Federal jurisdiction. Nor for very practical reasons could a system of dual inspection be instituted so as to examine separately nursery stock going to other States and that to be distributed within the State; at the time inspection must be done no one can segregate the nursery plants into these two categories, nor even forecast the proportions of any lot which will eventually reach these two distribution channels. The actual inspection procedure must therefore be carried out without reference to eventual outlets, and the sensible course is to leave both phases in the hands of the State.

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[1] S. R. A. (Service & Regulatory Announcement), Fed. Hort. Bd., 1926; p. 62.

In this illustrative case, as well as widely elsewhere, the Federal government has refrained from exercising to the full its right to control interstate commerce and has preferred to rely to a large degree on State quarantine action, usually well supported where needed by the Federal cooperation above mentioned.

Federal withdrawal in this way from its own proper field is, of course, legally sanctioned. Following the Supreme Court decision of 1926[2] which strongly favored Federal assumption of its responsibilities in matters of interstate pest spread, the numerous practical difficulties to be met in adopting an extreme policy in this field became apparent, and Congress by joint resolution in 1926 clarified the Federal-State relation by ruling in effect[3] that until the Federal authority has acted in a given pest situation in interstate commerce the State may take such protective action as it deems necessary. This dictum established the right of the several States to control and regulate incoming plant materials for pest reasons, when no Federal measures were in effect on the particular subject in question. This resolution has since served as a sound basis for the validity of the various State quarantines of interstate nature covered in this review.

State quarantine and regulatory activities fall rather naturally into two categories: those that attempt to prevent the entrance of crop pests into the State from areas outside its borders; and second, those designed to suppress, control, or prevent the spread of pests within the State's own territory. The latter group includes in turn both the specific quarantine measures relating to individual pests or well-marked problems affecting the State's internal welfare, and also those activities of general or service nature carried out under authority of the State's legal powers, such as nursery inspection, seed potato certification, and the like.

It may be remarked in passing that the service element in many of these intrastate activities may be present to such an extent that it quite overshadows the accompanying exercise of legal powers. In fact the quarantine and regulatory field shades off at times into situations where legal powers are not invoked and the problem is handled on the basis of a technical service assistance to private enterprise. Seed potato certification and field or vegetable seed certification furnish examples representative of both regulatory and nonregulatory types.

The present review attempts to deal only with those activities concerned in interstate relations, leaving for separate consideration those exercises of State power which are primarily intrastate in character.

The plant pathologist will readily recognize a number of factors favorable to the success of State quarantines which are intended to prevent or delay pest spread into the State from outside areas. In calling attention to the chief of these factors it is understood that an obverse relation would be more or less unfavorable to quarantine success.

It is obvious that a pathogen with a highly restricted host range, or one requiring an alternate host, or one low in propagation rate, or tied to the soil, or perishing quickly, is a less troublesome quarantine adversary than a pest species attacking numerous hosts, which produces enormous populations, is wind-borne, and has unusual longevity.

Again a quarantine has greater chances of success in cases where spread is largely dependent on the movement of carrier materials normally few in number, and traveling in well-marked channels easy to keep under surveillance.

The existence of effective control or treatment procedures is an important factor in quarantine prospects. A reliable treatment for hazardous pest carriers strengthens the quarantine position materially. So do rotation practices, resistant hosts, spraying methods, and similar control possibilities. In fact treatment and control may at times develop to a stage where resort to quarantine is judged to be unnecessary.

Another factor of prime importance lies in the effectiveness of survey and inspection methods. A quarantine is greatly weakened by having to depend on vague and unsatisfactory survey procedure or on unreliable inspection results.

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[2] S. R. A., Fed. Hort. Bd., 1926; p. 61.

[3] S. R. A., Fed. Hort. Bd., 1926; p. 62.

The volume and nature of movements also affect quarantines. It is difficult to regulate successfully a high volume movement involving varied types of commodities, especially where these represent great economic values, are in urgent demand, and may use a number of transportation channels.

The nature and extent of pest damage are also to be considered. Obvious and spectacular host destruction may arouse an earnest quarantine support, not always realized where the pest is of insidious or persistent type and the damage is less readily grasped and evaluated.

Finally, there is the matter of popular support. In a last analysis public approval and compliance are vital to the success of any large-scale quarantine undertaking. Whatever success may be obtained by an initial burst of administrative energy, results in the long run cannot exceed the level of public confidence and acceptance accorded to the measure.

Generally speaking, State quarantines can rely only occasionally on the automatic protection afforded by mountains, seas, plains, deserts, and other natural features. Climatic differences are usually too small to be significant. And a well-developed road network often permits endless truck and auto traffic beyond the control of any practical State supervision effort. Because of these limitations and handicaps State quarantines can only succeed in exceptional circumstances in permanently excluding an undesirable pest. In the main their greatest value lies in delaying the advent of pests so as to permit gradual adjustment, or the working out in advance of effective control measures.

When the field of plant diseases is examined in the light of these factors, some favorable and some unfavorable to quarantine action, it is evident that the situations where quarantine action is likely to be profitable are not so numerous as one might think. Excluding the biologically hopeless cases, those too costly to be undertaken, those well enough taken care of at-source, and those in which successful control methods largely obviate the need for regulatory action, the disease problems in which prevention of spread would be accomplished by quarantine methods are greatly lessened. Among these few, however, will be found cases where the primary object is to keep individual lots of planting stock free from some objectionable pest already widely distributed, or to protect long-term plantings, such as orchards, from early pest introduction, or to avoid local establishment of a pernicious parasite. Quarantine action may be justifiable for these specific purposes, as well as for preventing large-scale areal spread.

QUARANTINES AT-SOURCE

State quarantines designed to prevent the interstate spread of pests may adopt two distinct patterns. In the most simple and direct type the State authority attempts to prohibit or regulate the incoming movement of pest-carrying materials from infected areas in another State or States. In the second type the State where the pest occurs sets up a system of quarantine control and safeguards, effective for its own internal needs, and at the same time serving to prevent dissemination of the pest to other States; it is assumed that these outlying States will accept this arrangement as adequate for their protection. For convenience these two types may be designated as "destination" quarantines and "source" quarantines.

The idea of preventing spread at-source is biologically sound. It has wide practical acceptance in such matters as nursery stock inspection, seed potato certification, and the like; and it has been frequently adopted in individual quarantine situations since the early days. The economy of effort in this scheme is obvious, since effective action at source may obviate the need for numerous individual quarantines by the many States nedeing protection. Further, this method avoids certain enforcement weaknesses likely to diminish the value of destination-State quarantine action, especially where the volume of movement is large and traffic channels are so many and varied that surveillance becomes difficult and costly. Finally, the source-State quarantine fits more easily into normal commercial practices and thus causes less disruption and irregularity in commodity flow.

While it is thus evident that the quarantine at-source represents a higher plane of quarantine organization and efficiency than the destination-State type, the former must depend very heavily on mutual confidence among State officials for its success. In entrusting his State's welfare to the good faith and competency of officials in another State an administrator to some extent gives over into other hands his own special responsibility for his State's protection. The advantages from this step may justify its adoption in many cases, but it is quite understandable that a responsible official would be reluctant to agree to this plan where the protection offered his State did not seem adequate, or where a particularly destructive pest was concerned, or where a vital industry in his State was threatened. In these more serious situations an administrator could scarcely be blamed for falling back on the direct destination-State type of quarantine action, which with all its defects retains protection measures in the State's own hands.

An important element in these prominent situations, from the point of view of acceptance of the quarantine at-source plan, is the extent to which Federal interest and cooperation enter into the picture. Where a deep and active Federal concern is present, State acquiescence in the common program is likely to be materially strengthened.

STATE TERMINAL INSPECTION

The terminal inspection of nursery stock is an outstanding element in the quarantine organization of several States. While the State by virtue of its retained original State powers has all the legal authority needed to conduct inspection in connection with public carriers such as ships, trucks, railroads, and airplanes, as well as autos and other private vehicles, a problem arose early in quarantine development in connection with parcel post shipments of nursery stock and other plant products carried interstate in the United States mail. The State's inspection power could be exercised on such parcel post shipments only after delivery to the addressee, a procedure obviously impractical from the administrative standpoint. To relieve this situation legislation in 1915[4] enabled the U. S. Postal Service to set up an orderly procedure for State inspection before delivery of all packages containing specified kinds of nursery stock, and to require for such packages an external statement of contents, as well as a nursery stock certificate issued by a State or Federal inspector.[5] The plan further provided that a State desiring to undertake this inspection should submit a list of the types or classes of nursery stock for which predelivery examination was needed, as well as the pests concerned, and that this list should be approved to the Post Office Department by the Secretary of Agriculture. Under this arrangement the States specify the inspection places to which parcels are to be routed and there made available for the State inspector's examination.

In this scheme the State's inherent right to inspect materials entering its borders was recognized, and participation in the plan represented a definite Federal cooperative relation with each State concerned. It was understood that, although this provision for terminal inspection included the right of the State to refuse entry, or to treat, or otherwise safely dispose of materials found to be infested with injurious pests, it did not originally contemplate Federal responsibility for the enforcement of State regulatory restrictions or requirements imposed on interstate movement. The arrangement permitted inspection and the safe disposition of the specified products if infested, but nothing more.

However, this cooperative relation was broadened in 1936 by an amendment to the Postal Laws and Regulations[6] which charged the postal service with the duty of aiding States in the enforcement of State quarantines and regulations pertaining to injurious pests. After these State quarantine measures had been formally approved by the already established procedure, the Postal Service agreed to withhold delivery of and submit for State disposition parcels moving interstate in violation of the prohibitions or regulations imposed thereby.

At the present time[7] 11 States, Hawaii, the District of Columbia, and Puerto Rico maintain the terminal inspection procedure. Four States have discontinued this feature--Georgia (1933), Louisiana (1945), Oklahoma (1944), and Wyoming (1933).[8]

SCOPE AND LIMITATIONS OF THIS REVIEW

A summary of State and Territorial quarantine and regulatory measures was prepared by the Division of Domestic Plant Quarantines in 1930[9] and is being kept current by revision in mimeographed form as a separate B.E.P.Q. 578 for each State, Territory, and the District of Columbia. This publication gives a digest of the specific quarantines, rules, and regulations of the various States and Territories and the District of Columbia, and also covers their requirements for interstate movement of nursery stock into them from other States. The present review therefore does not attempt to list these measures by States but proposes instead to treat them from the host and pathogen standpoint, an approach more acceptable perhaps to the plant pathologist.

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[4] S. R. A. Fed. Hort. Bd., 1915; p. 20; Terminal Inspection Act of March 4, 1915.

[5] S. R. A. Fed. Hort. Bd., 1926; p. 24.

[6] S. R. A., B.E.P.Q. 1936, p. 180. Post Office Order No. 9620, October 15, 1936.

[7] B. E. P. Q. 578; Summary of State nursery stock shipping requirements and plant quarantines and regulations affecting interstate shipments. 1949 (Mimeographed).

[8] S. R. A., B.E.P.Q. 1941; Cumulative Index 1914-41, pp. 82-83.

[9] U. S. D. A. Miscellaneous Publication No. 80, Summary of State and Territorial Plant Quarantines Affecting Interstate Shipments. July 1930; Revised, March 1946.

In presenting these in detail, it is necessary to note that while these States make use of varied designations -- quarantine, order, rule, regulation, prohibition, restriction, requirement, and the like -- all of these terms represent some exercise of the State's legal authority for preventing pest dissemination.

The highly important item of nursery stock inspection is so well established and so universal and uniform that it may be disposed of with a few general comments. In the first place, as indicated above, nursery inspection follows the at-source pattern rather faithfully. Except for certain specific diseases, and for the terminal inspection arrangements elsewhere mentioned, it is customary for each State to rely on inspection in the State of origin, with the sanitary status of each shipment indicated by a certificate or permit of some sort. Although there are considerable variations in the concept of what constitutes "nursery stock" among the States, as well as differences in the inspection standards and procedures, enough uniformity exists to permit a liberal interstate exchange of planting materials.

A pathologist might complain that the nursery inspection system is heavily concerned with insect problems, and that its methods are much better adapted to entomological than to pathological needs. In justice it should be said that this situation may mean, on the one hand, that ordinarily inspection is easier for insects than for diseases, and that insect treatments are likewise more effective; and, on the other hand, that popular demand lays more stress on insects than on diseases. When pathologists have created an insistent demand for disease-free nursery stock and have provided means for making it so, this apparent unbalance will, no doubt, correct itself readily.

This review has aimed to include all State quarantine actions of interstate character. Although every effort is made to keep the Divisional information files complete and current, it is quite probable that a few of these quarantines have been overlooked or have not yet come to our notice. For any omission of this sort apology is offered.

ALMOND VIRUS DISEASES -- See under Prunus Virus Diseases

APPLE RUST (Gymnosporangium juniperi-virginianae) -- The only State taking quarantine cognizance of this disease is New Mexico, which by law (Ch. 118, Sec. 4; 1937) prohibits entry into the State of eastern red cedar, Juniperus virginiana, to protect its apple orchards and its native cedar, J. scopulorum, from this rust.

APPLE SCAB (Venturia inaequalis) -- The Regulations issued under Utah law, No. 3, effective June 10 1947, provide for inspection of all apples (fruits) entering the State on account of apple scab. This same regulation applies to pears on account of pear scab (Venturia pyrina).

Inspection of fruits for apple scab is generally regarded in other States as falling into market-grade procedure rather than as a measure to prevent scab dissemination.

APRICOT VIRUS DISEASES -- See under Prunus Virus Diseases

AZALEA FLOWER SPOT (Ovulinia azaleae) -- Three States (Oregon, Washington, and Texas) regulate the entry of azaleas from the South Atlantic and Gulf States on account of this disease, and Washington and Oregon include Rhododendron and Kalmia. Certificates are required by Oregon and Washington (Washington, Q. Order 28, Oct. 19, 1944; Oregon, Q. Order 47, July 1, 1943) to establish that the plants were grown in soil free from the pathogen and that surface soil was removed. Texas (Q. 129, Nov. 6, 1940) requires a spray or dip procedure, and absence of old leaves, flowers, and mulch.

In effect, these regulations are all merely special applications of the standard nursery stock inspection procedure.

BAMBOO DISEASES -- See under grass plants

BLUEBERRY STUNT (virus) -- Michigan (Quarantine No. 606; Sept. 1, 1944) is the only State to take action regulating the entry of blueberry plants and scion wood on account of this disease. Entry is conditional on freedom from this virus trouble as established by State-of-origin certificate.

BRAMBLE PLANTS DISEASES -- See under Rubus Diseases

BROMELIADS DISEASES -- See under Pineapple

BUTTERNUT BUNCHY DISEASE -- See under Walnut

CABBAGE PLANTS -- See under Seedling Vegetable Transplants

CHOKECHERRY X-DISEASE -- See under Prunus Virus Diseases, Peach X-Disease

CORN DISEASES -- See under Grass Plants

CRANBERRY FALSE BLOSSOM (Virus, Chlorogenus vaccinii) -- Since, according to Holmes, this virus probably originated in Wisconsin and was spread from there to other northern cranberry States, Wisconsin Order No. 6 (Jan. 1, 1928), requiring certificate of freedom from this trouble within a small tolerance for entering cranberry plants, must be regarded as a measure to keep down infection in new plantings or to avoid introduction into clean cranberry bogs, rather than as a quarantine step with a broad geographic objective. Perhaps on account of the success of flooding and spraying to kill the leafhopper vector and some reported varietal resistance, resort to quarantine has not been considered necessary in other States.

CAMELLIA FLOWER BLIGHT (Sclerotinia camelliae) -- Seven southern States have set up quarantine restrictions on camellia to prevent introduction into their extensive and valuable camellia nursery and garden cultures of this flower blight fungus, apparently a relatively recent immigrant from Asia to the West Coast States. The almost uniform regulations for these States, apparently worked out by Southern Plant Board discussion, bar the movement into them from infected western sources of balled and potted camellia plants and camellia cut flowers, but allow entry of bare-rooted camellia plants with petals still unopened at the time of shipment and so certified at source. Four States (Alabama, Louisiana, Mississippi, and Tennessee) require affidavits from camellia shippers in States maintaining no restrictions against camellia flower blight that they have not received or will not receive restricted materials from the respectively designated infected areas.

Measures of this type have been promulgated by Alabama (Quarantine No. 4; Dec. 15, 1949); Florida (Rule 51; June 24, 1949); Georgia (Quarantine No. 9; July 1, 1949); Louisiana (a quarantine order of July 20, 1949); Mississippi (Rule 71; June 22, 1949); South Carolina (Quarantine Order of August 1, 1949); and Tennessee (Quarantine Notice No. 14; July 1, 1949).

While these actions aim to exclude the flower blight pathogen, their precautionary character is indicated by the fact that there could be no previous survey assurance of a general freedom of the areas in question from this flower blight. This situation illustrates a not unusual quarantine difficulty -- the necessity of taking quarantine action before there is adequate knowledge on pest distribution. It may be noted also that since air dissemination by conidia is lacking and infection must be effected by direct ascospore discharge from the wintered sclerotial stage, the prospects for reasonably effective local control tend to lessen the pressure on quarantine methods.

CHESTNUT BLIGHT (Endothia parasitica) -- The now practically complete infiltration of this destructive Asiatic fungus intruder into all the eastern range of the chestnut and chinquapin has for years provided a spectacular and extreme example of pest damage. Protected by a broad prairie and desert belt and lacking native chestnut forests, the Pacific Coast States and western Canada have had to contend with only a few scattered introductions of the disease, all of them now eradicated or in process of elimination. Because of increased interest in chestnut production in these States four of them have established quarantine barriers to prevent the entry of infective materials from eastern sources. All these measures by California (Quarantine Procl. No. 2; Jan. 19, 1935); Idaho (Quarantine Order No. 16; Apr. 29, 1939); Oregon (Quarantine Order No. 27; Feb. 5, 1937); and Washington (Quarantine Order No. 8; June 10, 1927) prohibit entry into the State of trees or plants, nuts, grafts, cuttings, and scions of chestnut or chinquapin from States east of and including Montana, Wyoming, Colorado, and New Mexico. California and Idaho had established earlier restrictions in 1927 and Oregon in 1935, which the measures cited have superseded.

The effectiveness of prohibitory action as compared with regulated entry, the natural protection afforded the West by the prairie and desert strip, and the highly developed interest of the Pacific Coast States in pest protection methods are all favorable to the success of these protective measures.

The State of Arkansas is the only other State with chestnut blight quarantine restrictions. This State (Rule 56; Dec. 11, 1937) regulates by a permit system the entry into it from outside sources of plants, plant parts, and seeds of chestnut and chinquapin.

CITRUS: VARIOUS DISEASES INCLUDING CITRUS CANKER (Xanthomonas citri) -- The citrus-growing States have imposed very stringent restrictions on citrus fruits, seeds, and nursery stock, partly on account of fruit flies, scales, and other insects, and partly on account of important diseases of these hosts, among which citrus canker is outstanding.

Five States having important citrus interests have established special regulations on the entry of citrus nursery stock (plants, cuttings, budwood, seeds). In the other Gulf and Southern States, and in Puerto Rico, citrus diseases are taken care of in conjunction with insect quarantines or as a part of the standard nursery stock inspection procedure.

Alabama (Nursery Regs.; revised; Sept. 24, 1943) allows entry of citrus nursery stock under a permit system. An official certificate from the State of origin must establish freedom for two years from citrus canker, scaly bark, and other important citrus diseases, both in the nursery production center and its environs; further , complete defoliation is required.

Arizona (Quar. Order No. 5, amended; 1948), likewise uses the permit system for nursery stock introductions, requires defoliation, and stipulates a three-year period of freedom from citrus canker to be established by certification at origin. Citrus fruit must be so certified also.

California (Quar. Procl. No. 1, revised; Dec. 2, 1948) does not require a certificate from the State of origin for citrus nursery stock, fruit, or seeds, but depends on its own permit tags issued to the authorities of the State of origin to be used only on shipments from areas determined by California to be free from canker (and other serious citrus pests) for a three-year period. In the case of fruit, California calls for annual surveys in the production State to assure current freedom from canker and fruit fly pests.

Florida (Rule 28, revised; March 22, 1947) prohibits the entry of all domestic citrus nursery stock materials, including seeds and fruits, except for shipments by the U. S. Department of Agriculture, and for new citrus type stock for which a special permit is secured from the State Plant Board. This extreme action is taken on account of citrus canker, the quick decline of citrus, and other serious citrus diseases. There are also special restrictions placed by Florida (Rule 30, revised; March 22, 1947) on citrus fruits from Arizona and California on account of the brown rot of lemons and oranges (Phytophthora citrophthora).

Texas (Citrus Nurs. Stock Regs.; Feb. 4, 1946) allows the entry of citrus seeds from areas free from citrus canker or quick decline and so certified, and requires their disinfection with corrosive sublimate. In regard to citrus nursery stock, Texas follows the California plan of permit or license, based on the Texas official's knowledge of disease conditions at source, but requires also a State-of-origin certificate.

COCONUT BUD ROT (Phytophthora palmivora) -- To supplement its internal measures for the control of this disease, Puerto Rico has included in its plant pest Act (No. 35; May 11, 1934; amended May 14, 1948) a stipulation that coconut trees, nuts, or other raw coconut materials shall be certified at origin that the district of production is free from bud rot or other coconut disease or insect pest not widely prevalent in Puerto Rico. Here, as in several other situations noted, the action taken, although embodied in the organic pest act, must be regarded essentially as a special case in the nursery inspection field.

COFFEE DISEASES -- Puerto Rico (Quar. No. 4; July 30, 1948) aims to protect its coffee industry by generally prohibiting entry into the Island from other United States areas plants and seeds of coffee, except as may be authorized under a permit arrangement for experimental purposes. Roasted coffee beans and their ground products are excepted from this quarantine, which is mainly designed to avoid introduction of coffee rust, Hemileia vastatrix. This quarantine is complementary to Federal Foreign Quarantine No. 73, which protects the Island's important coffee cultures against pests and diseases from other countries.

Hawaii also maintains a quarantine on coffee (Reg. 1.3; Aug. 14, 1947), which brings under a permit procedure all coffee plants or plant parts or seeds for propagation purposes from elsewhere in the United States. The quarantine board may authorize limited entry for propagation purposes under conditions considered safe and when needed in the public interest.

COTTON DISEASES -- Three States and Puerto Rico have issued regulations relating to or including diseases of cotton. Nevada, in setting up a special cotton district in the State, requires by the terms of its seed law regulations (April 15, 1949) that seed cotton, unprocessed cottonseed, or unginned cotton shall enter such district from elsewhere in the State or from outside the State under a permit system, presumably to avoid introduction of (unspecified) plant diseases and other cotton pests. The primary intent of the regulations appears to be intrastate in character, and although its interstate feature is clear enough, this element represents almost the minimum of interstate quarantine regulation.

Arkansas is somewhat more specific in its seed law regulations where Rule 68 of August 22, 1939, provides that cottonseed for planting purposes shipped into the State shall bear a State-of-origin certificate establishing a reasonable freedom in the field where grown from anthracnose, wilt, and other serious communicable diseases.

Oklahoma (Quar. Order No. 4; Sept. 1, 1944) quarantines cottonseed from all out-of-State sources on account of anthracnose (Glomerella gossypii) and bacterial blight (Xanthomonas malvacearum). The permit system is used, and along with the customary shipment procedure treatment of the seed with Ceresan is a requirement.

The cottonseed and cottonseed products' regulations of Puerto Rico are also of minimum nature. Its plant pest Act (No. 35; May 11, 1934) stresses the exclusion of cotton boll weevil but includes as reason for restrictions also "any other cotton pest or disease not widely prevalent in Puerto Rico." A certificate by the State of origin with power of inspection on arrival is the indicated procedure here.

EASTERN FILBERT BLIGHT (Cryptosporella anomala) -- The considerable filbert industry developed in recent years in the three Pacific States has long been apprehensive of the establishment there of the leaf blight fungus indigenous on the natural Corylus species of the East. Quarantine measures promulgated by California (Quar. Order No. 4; Jan. 22, 1927), Oregon (Quar. Order No. 20 A; revised Feb. 5, 1937), and Washington (Quar. Order No. 6; June 10, 1927) aim to prevent the westward spread of this apparently destructive pathogen by excluding all trees, plants, cuttings, scions, or grafts of both cultivated and wild filberts originating in the infected area -- that is, the territory east of and including the States of Montana, Wyoming, Colorado, and New Mexico.

The uniformity of action taken by these States doubtless reflects the helpful results of a cooperative approach promoted by the Western Plant Board.

ELM DISEASES: DUTCH ELM DISEASE (Ceratostomella ulmi) AND PHLOEM NECROSIS VIRUS DISEASE -- The only State which has invoked quarantine methods to prevent the entry of these elm troubles is California (Quar. Procl. No. 21, July 19, 1947; amended June 5, 1948), which lists a wide group of States as infected from Arkansas and Colorado east, and prohibits entry into California from them of trees, plants, and all parts of these; elm logs or cordwood; and lumber and other materials or articles containing elm wood not free from bark. From uninfected States materials capable of carrying these diseases or its insect agents of transmission are required to bear certificates establishing freedom of their local sources from these diseases.

It will be observed that this quarantine has both prohibitory and regulatory features in a combination designed to secure the maximum protection to the State with a minimum of interference in normal movement of articles and materials.

GLADIOLUS CORM DISEASES -- Michigan (Reg. No. 611; May 13, 1947) has set up certification requirements for the production of gladiolus corms within the State, and has established tolerances for the several diseases of these corms. This certification procedure is intended to serve intrastate needs and at the same time give assurance of a standard product for shipments to other States. While this quarantine action is technically of purely intrastate character, it is apparently intended to serve as one of the several at-source measures proposed as a means of providing general interstate protection in the movement of gladiolus.

A similar measure by Kansas (Entomological Com. Rules and Regs. 7-1-32; June 10, 1948) provides for two field and one or more storage inspections, as well as a tolerance schedule for diseases present. It is indicated that gladiolus corms offered for sale in Kansas must meet an equivalent standard and be so certified.

Both these measures appear to have taken form out of the deliberations of the Central Plant Board on the subject. It is clear also that the procedure adopted represents a special case of the general nursery stock scheme, and that in its interstate relations the protection-at-source pattern is used.

GRAPE, PIERCE'S DISEASE (virus) -- Another special case of quarantine of nursery stock type is found in the Arizona Quarantine Order No. 17 (Reg. 1.1; Aug. 14, 1947), which requires that plants and propagative parts (except seeds) of grape will be accepted from California and Texas only when accompanied by a certificate establishing that the plants or cuttings in the shipment were obtained from a location where this virus disease is not known to exist within a radius of one mile. As in other cases of this type the scheme of protection at source as adopted.

GRASS PLANTS -- The typical State quarantine is of more or less specific nature, covering a single outstanding pest, or a single crop plant or a closely related group of hosts. The Territory of Hawaii (Reg. 1.1; Aug. 14, 1947) has departed somewhat from this model by issuing a quarantine on a variety of grass plants, on account of pests and diseases in general. While sugarcane looms importantly in this picture, there are also included bamboo, corn, sorghum, and other members of the Gramineae.

The use of a permit system allows the quarantine authority to exercise its best judgment on both the admissibility of certain propagating materials of the grass species concerned, and the conditions which would be required for their safe entry. This flexible type of procedure thus assures the maximum liberality in entry without sacrificing the important element of safety.

KALMIA, Ovulinia azaleae -- See under Azalea

NARCISSUS BULBS -- Three States which have developed an extensive production of narcissus bulbs aim to protect this industry from further introduction of certain eelworms, primarily the bulb nematode (Ditylenchus dipsaci Kühn). Since this nematode has long been widely distributed throughout the country, the quarantine objective is not to protect the State from a new and hitherto unknown pest, but to insure clean planting stock for gardens and propagation fields. Thus these quarantines fall naturally into the nursery stock category as special cases.

In all three States the protective scheme sets up inspection, treatment, and certification procedure for the State's own narcissus bulb production, and then requires a similar procedure for bulbs entering the State from elsewhere, compliance with such standard to be established by certification at the production source.

In Washington (Quar. Order No. 5; Sept. 10, 1946) and Oregon (Quar. Order No. 54; Dec. 10, 1946), as well as in North Carolina (Quar. No. 6, revised; Jan. 8, 1941), the standard hot water treatment is prescribed for infested bulbs.

Both Washington and Oregon provide also for the use of formaldehyde in connection with this treatment. North Carolina includes the narcissus bulb fly (Merodon equestris Fab.) as a reason for quarantine and where this pest alone is present prescribes a shorter hot water treatment or cyanide fumigation.

NECTARINE VIRUS DISEASES -- See under Prunus Virus Diseases

ONION PLANTS -- See under Seedling Vegetable Transplants

ORCHID PLANTS: VARIOUS PESTS AND DISEASES -- While orchid plants would seem to deserve no more quarantine attention than many other exotic ornamentals, such as the saxifrage group or cactus, the species of which are usually classed along with numerous others as of regular nursery stock type, yet the wide range of the orchid family, its horticultural popularity, and particularly the considerable economic values it often represents, justify special quarantine consideration under some circumstances. The Territory of Hawaii, because of its climatic advantages and interest in floral development has been outstanding in orchid culture, and has issued a quarantine (Reg. No. 1.5; Aug. 15, 1947) of the usual type, providing for the entry of these plants under permit so that they may come under orderly inspection and be freed from accompanying pests before being released into horticultural use. A certificate by the State of origin is required; a greater pest risk is recognized in orchids from tropical as compared with those from temperate regions; and a system of quarantine detention is set up for plants or shipments of doubtful status.

PEAR SCAB Venturia pyrina -- See under Apple Scab

PRUNUS VIRUS DISEASES -- From the quarantine point of view the virus diseases of various members of the stone fruits constitute a rather sharply defined group. None are known to affect naturally hosts outside the family; none are juice-transmitted; insect vectors where known are usually single species or closely related species; all these diseases are systemic and persistent; and recognition depends largely on characteristic growth abnormalities in the host. The limited host range simplifies the quarantine problem materially; inability to spread by pruning and other normal operations is also a distinct advantage; but much uncertainty is introduced by the difficulty of sure detection and by lack of adequate knowledge on critical virus and vector relations.

Prunus virus diseases have been outstanding subjects for quarantine action among the States. Not only are Prunus fruits of high economic value, widely grown, and universally popular, but the virus diseases peculiar to these orchard crops are unusually numerous, and at times very destructive. Over 50 of these virus troubles are recognized, of which a large majority are suspected to be indigenous; at least evidence of foreign origin is in most cases not at all conclusive.

State quarantine measures for these diseases have in nearly all instances centered on nursery stock movement, since the fruit and seeds have been shown to transmit these viruses only in exceptional cases. For many States some or all of the Prunus virus troubles are merely included in the normal nursery stock plan of protection. Where quarantines are imposed the State either relies on its own special protective restrictions or the scheme of quarantine at-source is adopted, the latter solution being usually accompanied by active Federal cooperation.

Because of the difficulties in detection, the existence of a symptomless incubation period, and the possibility of symptomless carriers, direct inspection of nurseries is often supplemented by the requirement of a virus-free zone around the nursery, and in some cases its bud-sources. This is a precautionary requirement adopted as the only available means of preventing local virus spread to the nursery plants.

Mention should also be made of the pronounced present trend toward the establishment of indexing procedures intended to maintain virus-free plant sources for use in propagation. This important development represents a distinct step in Prunus virus disease control, although it can only start an orchard with healthy stock and cannot prevent the intrusion of local virus infection during the relatively long life of the orchard afterward.

Some of the Prunus virus diseases appear to have areal limitations. It is not always clear whether these are climatic in nature or correspond with vector distribution or are due to other variable factors. Such limitations must be duly considered in quarantine planning.

In the light of these general features, a summary may be made of the various quarantines dealing with Prunus viruses.

Peach Mosaic (Marmor persicae): Peach mosaic is a troublesome orchard control problem at times in the eight Southwestern States where it occurs, and a persistent campaign is being waged by these States cooperatively with the Federal government to reduce or suppress it effectively in commercial peach plantings. Interstate quarantine interest, however, centers in the problem of preventing spread through nursery stock movement. Certification by the State of this nursery stock for interstate shipment includes maintenance of inspection over the one-mile environs of nurseries and budwood sources, and early-season removal of all mosaic-infected trees therefrom. Federal and State inspectors combine their forces in a comprehensive program, under general Federal supervision to unify effort over the whole area, and undertake in joint fashion this nursery inspection, the orchard inspection work, and the survey of new territory for mosaic.

This large-scale cooperative attack has been made possible, first of all by State agreement in the common plan; second, by the issuance by the States concerned of a uniform series of practically identifical quarantines; and third, by the character of these quarantines, which being of the at-source type aim to protect distant States from danger of mosaic spread, as well as to serve the internal needs of the issuing State. This whole arrangement may be said to represent the highest plane of organized quarantine effort yet attained in the interstate field.

The peach mosaic problem is a recent development. The disease was found and recognized in 1935; and the project was not organized on its present basis until 1937. The States now actively participating are: Arizona (Quar. Order No. 9; revised, March 31, 1947); Arkansas (Quar. Order No. 1; Nov. 11, 1949); California (Quar. Procl. No. 14, revised, Jan. 29, 1945 and amended Feb. 6, 1947); Colorado (Quar. Order No. 1; May 1, 1942; and Quar. Order 9; Oct. 15, 1946); Oklahoma (Quar. Order No. 1; Aug. 15, 1944, and amended Dec. 15, 1944); Texas (Quar. Order No. 6, amending No. 5; Jan. 5, 1945); and Utah (Quar. No. 1, revised; June 10, 1947).

Mosaic occurs in New Mexico but both the State's nursery production and its commercial peach plantings are not on a scale to justify the cost of this general inspection program.

Two States, Georgia (Quar. Order No. 2; Feb. 4, 1946), and Idaho (Quar. Order No. 21; (N.S.) revised; Aug. 1, 1949) have preferred to protect themselves against peach mosaic by issuing quarantines against the mosaic States.

Peach Phony Peach (Nanus mirabilis): -- Although known as an obscure orchard trouble in Georgia since the eighties, the virus nature of phony peach was not established until 1929, at which time a Federal-State eradication program was undertaken in Alabama and Georgia, backed by State and Federal quarantines. The Federal quarantine (No. 69; June 1, 1929) was revoked March 1, 1933, owing to the widespread distribution determined by extensive surveys. Federal cooperation has been actively continued, however, and the State quarantines with revisions from time to time have remained in effect.

From the quarantine standpoint the phony peach problem closely parallels that in peach mosaic. Each disease is present in somewhat limited areas; both require trained inspection for orchard detection; control in both cases relies on prompt removal of diseased trees; in both constant general survey is needed; and for both quarantine interest centers on prevention of spread through supervision of nursery stock movement. It may be added that both problems are handicapped by lack of knowledge on critical features, and largely for this reason both resort to safety-zone or environs inspection procedure. In phony peach, however, the incubation period is longer (18 months or more) and inspection of budwood sources has not been found necessary owing to failure of transmission by budding methods.

Because of this close correlation Federal cooperation combines the two diseases into a single administrative project, and since 1936, by agreement with the States concerned, a uniform program has been worked out for both, as discussed under peach mosaic. In this common enterprise, inspection resources are pooled for survey, orchard inspection, and nursery inspection; and in the customary way the State certifies for interstate movement the nursery stock found by the combined inspection to be eligible under the general program agreement. It may be noted here that since this program was instituted, no evidence has appeared which would indicate that spread of either disease is taking place by means of nursery stock movement.

No attempt is made here to cite the various State quarantines and their numerous revisions covering the period since 1929. At the present time the State quarantines on phony peach are all practically identical in content, covering, by name, counties in which the disease occurs, and requiring a State-of-origin certificate on all peach or nectarine trees with roots or trees grafted on peach or nectarine roots, out of this infected territory. These States are as follows: Alabama (Quar. No. 1; Mar. 3, 1939); Georgia (Quar. No. 1, revised, Feb. 21, 1949); Illinois (Quar. Procl. as revised March 15, 1947); Louisiana (phony peach disease regulation, revised; July 1, 1937); Mississippi (Rule 64-A; amended, Feb. 14, 1947); Missouri (Quar. No. 1, revised; Feb. 20, 1947); South Carolina (Quar. Order No. 1, revised; Feb. 24, 1949); Tennessee (Quar. Notice No. 11, revised; March 29, 1948); Texas (Quar. No. 5, amending No. 4; Jan. 5, 1945).

It should be noted that Florida is not included, although phony peach is present there; the State's peach culture is too small to justify this type of quarantine action. Again Illinois maintains the standard type of quarantine, although no phony peach has been found there for some years. Finally it is noteworthy that the numerous other peach-growing States appear to accept this protection-at-source method of handling the phony peach problem as affording them an adequate safeguard against the disease.

Peach Yellows and Related Diseases: Five Western States have set up quarantine barriers against introduction of peach yellows, little peach, and peach rosette (Chlorogenus persicae var. vulgaris, C. persicae var. micropersica, Carpophthora rosettae). These measures affect propagating materials of almond, apricot, nectarine, peach, and plum coming from the eastern area of known occurrence of these diseases.

The Oregon Law (Compiled Laws, V. 4, Sec. 35-205; regs. 1946) covers only peach, nectarine, and apricot; includes fruit pits; and requires State-of-origin certification from the quarantined area that such nursery stock was grown in a disease-free area and that the bud source and environs were also free from these diseases. Arizona (Quar. Order No. 8; 1939; revised, Jan. 5, 1945); California (Quar. Procl. No. 11; Jan. 13, 1945); Idaho (Quar. Order No. 3; revised, Aug. 1, 1949) and Washington (Quar. No. 9; Mar. 30, 1945) have practically identical measures, which allow entry of the materials mentioned when certified by the State of origin, but with certain differences. Arizona, Idaho, and California accord shipping approval for counties at origin certified as virus-free by the State authority through annual survey, and require the certification of bud sources and stocks as also virus-free. Washington maintains an embargo against the infected States and requires special certification from noninfected States.

Peach Yellows (Chlorogenus persicae var. vulgaris): The State of Virginia maintains in its code (Sec. 905, compiled laws 1945; 1889-90; p. 145, code 1919) an early law making it an offense to bring into or sell within the State any peach tree infected with peach yellows. The actual usefulness of this law is doubtful, owing to the difficulty of establishing before a court that the virus in a specific tree or lot was brought into the State and was not of local origin.

Peach Wart: California (Quar. Procl. 22; July 11, 1947) establishes restrictions on the entry of peach trees and parts thereof from Oregon, Idaho, and Washington, to exclude this virus disease. A State-of-origin certificate is required establishing that the growing ground, the budwood sources, and the environs of these for one-half mile have had no wart during the current and previous season.

Peach X-disease (Marmor lacerans): Taking cognizance of the gradual spread of this virus disease in New York and the New England States, and of the presence of a similar disease in Idaho, Utah, and Colorado, the State of New Jersey issued a quarantine (Jan. 17, 1939) shutting out budwood, scions, and other parts of peach from the States mentioned, as well as plants or parts of the chokecherry hosts (Prunus virginiana, P. demissa, and their varieties). To strengthen this measure, it is required that shipments of peach trees and peach propagating materials into New Jersey from elsewhere shall be marked to show origin.

The disease here referred to is now considered to consist of two entities -- the eastern and the western X-disease (yellow-red virosis). This later distinction would apparently not effect the validity of the New Jersey quarantine.

PEPPER PLANTS -- See under Seedling Vegetable Transplants

PEPPER SEEDS, BACTERIAL CANKER (Xanthomonas vesicatoria) -- Puerto Rico (Quar. No. 3; July 30, 1948) requires that all pepper and tomato seeds coming from the mainland must be treated with bichloride of mercury previous to shipment and be accompanied by a State certificate showing that this treatment has been given.

PERSIMMON WILT (Cephalosporium sp.) -- California (Quar. Procl. No. 19; Nov. 10, 1939) has established an embargo on all trees and parts of persimmon except fruits and seeds, prohibiting their entry into the State from elsewhere on account of the persimmon root borer (Sannina uroceriformis) and the Cephalosporium wilt. Justification for the embargo rests on the widespread distribution of the root borer and the lack of effective treatment for the internally borne wilt disease.

PINEAPPLE DISEASES, UNSPECIFIED -- The Territory of Hawaii (Reg. 1.2; Aug. 14, 1947) established a general quarantine on pineapple (plants or parts thereof, and fruits) and other bromeliaceous species, on account of certain specified insects and thrips, as well as pests and diseases in general. The object was the protection of the extensive pineapple industry from new outside pests. Under the terms of this measure, the restricted materials are enterable under permit, and may be held for official observation under prescribed detention conditions until release is approved.

A similar procedure is set up by Puerto Rico (Act No. 35 of May 11, 1934; as amended Apr. 15, 1946, and on May 14, 1948). Entry inspection, certificate by the State of origin, and special detention requirements are the outstanding features of this measure.

PLANT PATHOGEN CULTURES -- The propriety of imposing regulations on the interstate movement of living stages of injurious insects or plant pathogens was much discussed in early years. Specific Federal domestic quarantines have at times taken cognizance of the danger of pest introduction into a new area through transportation of these pests and culture materials by persons who were either irresponsibly unaware of the possible consequences of careless handling or were merely indifferent to this aspect of the situation. In some quarters justification for unrestrained culture movement was sought as a right inherent in the customary freedom of scientific research.

In recent years the trend of thought has tended to reconcile these two conflicting concepts. It is recognized that the research function is not sacrosanct and that a pest let loose in the course of investigation is just as destructive to the country's interest as if it were carried to a new locality by ordinary commerce. Consequently, control over one means of dissemination is as necessary as for the other. Further, with this recognition that national welfare must be the paramount consideration comes repudiation of the claim that supervision over culture movement connotes an unwarranted interference in research freedom. The present viewpoint looks upon culture movement as utterly outside the interest of the quarantine authority, State or Federal, so long as it is made under safe conditions. With this safety provided for, the quarantine administrator is not concerned as to the object of the research or the materials needed for it. Beyond a proper care that transported cultures do not endanger the public welfare, he has no slightest wish to control research in any way. A growing understanding of the two-sided nature of this problem is now building up excellent cooperative relations between quarantine agencies and research specialists, and it is believed that future procedures mutually satisfactory to both points of view can henceforth be easily arranged.

Several States have promulgated restrictions on the entry into them of living stages of injurious pests, which are generally considered to include not only insects but also fungi, bacteria, nematodes, and viruses. The provision in these measures for entry under permit is obviously intended to allow the most liberal possible movement of cultures consistent with safety in their handling, use, and ultimate disposal.

Alabama -- Agric. Laws of Alabama, Annotated, Code of Alabama, 1940, Sec. 461, art. 28, "Introduction of pests and diseases. -- The introduction into this State of any live insect or specimen of any disease injurious to plants, except under a special permit issued by the board or commissioner is hereby prohibited."

California -- Agricultural Code of Calif., Div. 2, Ch. 1, Sec. 110, "It is unlawful to import into or ship or transport within the State, except for the purpose of identification, any pest, live insect or disease, unless such shipment or transportation is authorized under written permit and the regulations of the director or the United States Department of Agriculture....."

Colorado -- State Entomologist Act of April 27, 1937, Sec. 10, "Unlawful to Transport Pests. It shall be unlawful for any person or persons, by any means whatsoever to knowingly transport, into or in Colorado, live pests which may be injurious to agriculture or horticulture in the State, except for scientific purposes, without permission from the State Entomologist."

Florida -- Florida Plant Act of 1927, Sec. 7, "The introduction into this State of any live insect or specimen of any disease injurious to plants, except under a special permit issued by the Board, is hereby prohibited."

Georgia -- The Entomology Act of 1937, as amended March 19, 1943, Sec. 11, "The introduction into this State of any insect in any stage of development or specimen of any disease injurious to plants, except under a special permit issued by the Director of Entomology is hereby prohibited."

Territory of Hawaii -- Regulation three of the Territory of Hawaii (Aug. 14, 1947) brings under restriction all cultures of fungi, bacteria, and viruses entering the Territory. Under a permit system, entry of these cultures may be authorized, subject to stipulated conditions of entry and utilization, and to an inspection procedure to verify identity.

Wisconsin -- Wisconsin Statutes 1943, Ch. 94, Sec. 544, "Permits for shipment of insects and pathogens. No person shall sell, barter, offer for sale, or move, transport, deliver, ship, or offer for shipment, any living insects in any stage of their development, or any living plant pathogens without a permit from the Department of Agriculture, issued upon compliance with the conditions and regulations which the Department is authorized and directed to prescribe .....Such permit shall be issued only after the Department has determined that the insects plant pathogens in question are not injurious to plants, animals, or other materials, if not already present in the State, or have not been found to be seriously injurious to warrant their being refused entrance, if known to be already established within the border of the State. Such permit shall be affixed to the outside of every container or shipment thereof."

PLANTS: CROWN GALL (Agrobacterium tumefaciens) -- Since crown gall has practically a universal distribution, and the organism itself can be carried invisibly on plant roots and in attached soil, regulations based on the presence of visible galls must be justified on advantage to the plant grower rather than as a means of preventing actual geographical distribution. Further, the high value of gall-free plants is unquestioned for some plant species, but less evident in other cases; and there appears to be some variation in crown gall injuriousness as between Northern and Southern States.

When these uncertainties are considered, along with inspection difficulties and limitations, the tendency among the States has been to adopt a compromise attitude toward crown gall. Many States are content to accept plants freed from visible galls as satisfactory; a few would require the rejection of all gall-bearing plants; and still others would object to any stock in which crown gall was present at digging inspection. In most cases, however, these attitudes can be satisfied in the normal nursery inspection procedure, without recourse to special quarantine promulgation.

Arizona appears to be the only State which has established special crown gall restrictions (Quarantine Reg. No. 3; Sept. 1, 1927; revised, May 17, 1944). In this measure the State refuses to accept any out-of-State plant or tree on which crown gall is found visibly present, and if over 50 percent of the plants in any lot show galls the entire lot will be rejected.

PLANTS: OZONIUM ROOT ROT, TEXAS ROOT ROT (Phymatotrichum omnivorum) -- The soil fungus here concerned attacks the root systems of a wide range of plants and can, of course, be spread by nursery stock or other types of rooted plants. The organism is said to be present in soil in at least parts of eight Southwestern States.

Three States attempt to shut out plant materials likely to carry this destructive soil fungus; California (Quar. Procl. No. 13, revised; Jan. 21, 1949); Mississippi (Rule 63; Jan. 1, 1930); and New Mexico (Quar. Order No. 11; June 30, 1937; revised Sept. 8, 1937).

Since the fungus occurs in decidedly patchwork fashion throughout the eight States, which include both California and New Mexico, the object of each quarantine is to prohibit shipment of soil, plants with soil, and rooted plants from the various root-rot areas, but not to extend restrictions beyond this justifiable minimum. New Mexico designates these areas by counties. California is less specific as to areas and relies on a certificate of the State of origin to establish eligibility for entry; and Mississippi quarantines on a State basis and depends on the certificate also.

PLUM VIRUS DISEASES -- See under Prunus Virus Diseases

PRUNE VIRUS DISEASES -- See under Prunus Virus Diseases

RHODENDRON, Ovulinia azaleae -- See under Azalea

RUBUS DISEASES -- The diseases of this group, which includes various bramble plants of blackberry, raspberry, and dewberry type, have given been considerable quarantine attention. Although widely varied in nature and behavior, the virus diseases, orange rust, and crown gall, with which quarantines are largely concerned, are seen to be widely distributed so that the quarantine objective is not so much to protect large areas from the introduction of a new pest as to avoid the disadvantages of bringing the pathogen into new plantings, or the infection of adjacent plants, or the contamination of clean soil. Thus the aim in general is to protect the individual grower's interests rather than the geographical area. Because of this viewpoint, the regulations imposed can be looked upon as special cases in the general scheme of nursery stock sanitation. The additional restrictions and requirements demanded in the States of origin and the certification procedures adopted all fall readily into the nursery stock pattern. Further, virus disease relations in the Rubus group essentially duplicate those encountered in seed potato certification, so that one might expect to find a certain parallelism of action in these two fields.

While this close relationship with the nursery stock pattern has been recognized in the quarantine promulgations of most States, which lump together the diseases of brambles or of raspberries, a few States have imposed individual quarantines for specific diseases. In a few cases also slight tolerances are allowed.

Seven States regulate the entry of raspberries and require some form of certification by the State of origin. The North Dakota regulation of 1931 covers virus and other diseases; so does New York (Order 23, amended Mar. 6, 1925); the other five in this group exhibit considerable uniformity of viewpoint, probably the happy result of Central Plant Board discussion and agreement. Wisconsin (Order No. 7; Jan. 1, 1930); Kansas (Rules and Regs. 7-1-29; June 1948); Minnesota (Quar. No. 6, revised, April 1, 1928); Michigan (Reg. No. 601; Feb. 4, 1947); and Ohio (Reg. Summary, Jan. 1, 1942), all deal with virus diseases and orange rust. All these five States, as well as New York, demand that the inspection and certification given by the State of origin shall be substantially equivalent to the protective procedure in effect in the recipient State. In addition, Ohio includes crown gall; Pennsylvania (bramble plant certification, May 15, 1939) apparently accepts the standard nursery stock certificate for the general field of Rubus plants but provides specially for crown gall inspection at destination. Washington State (Order No. 17; July 11, 1933) covers all berry plants along with strawberries and includes crown gall among the pests and diseases given as the reason for regulation.

SHALLOT DISEASES -- See under Onion

SORGHUM DISEASES -- See under Grass Plants

STRAWBERRY PLANTS -- See under Rubus Diseases

TOMATO PLANTS -- See under Seedling Vegetable Transplants; also under Potato, Root Knot Nematode

WALNUT BUNCHY DISEASE (Virus) -- This virus trouble has been recognized since 1913 as a virus trouble in the Southeastern States and has been observed since then from the Gulf States to Michigan. Its witches'-broom effect is particularly important on the butternut, *Juglans cinerea*, and on the Persian or English walnut commonly cultivated. The disease has not been reported west of the Rockies.

Owing to the growing importance of walnut culture in California, that State has issued a quarantine (Quar. Procl. No. 12; Jan. 28, 1949) as a protection against bunchy disease introduction from eastern sources. The action taken (1) prohibits movement from all States east of the Rocky Mountains of all plants and propagative parts (except seeds) of both wild and cultivated forms of *Juglans*; and (2) allows entry from States west of the Rockies under certificate establishing this western origin.

Because of a reasonable assurance that the Pacific Coast States are still free from this disease, and the negligible movement of walnut propagating stock into California from the East, the measures taken give considerable assurance of being able to prevent spread.

The quarantine cited also covers propagating materials of hickory and pecan trees (*Carya* spp.) in a similar way on account of certain nut tree casebearer insects (*Acrobasis* spp.).

WESTERN CELERY MOSAIC (Virus, *Chlorogenus callistephi* var. *californicus*) -- Two States, Arizona (Quar. Order No. 16; June 28, 1945), and Colorado (Order H; Feb. 1, 1948; amended 1949), attempt to protect the celery industry in each from this virus malady by prohibiting the entry of seedling host plants from all out-of-State sources. Since freedom from the disease is indicated for both States, these quarantine measures aim to protect the State as a whole, as well as its individual celery growers. The finished commercial plant product is not affected by the quarantine; risk of transmission in celery table stock is regarded as negligible.

VEGETABLE TRANSPLANTS -- Although the common vegetable seedlings and rooted cuttings (cabbage, onion, tomato, sweetpotato, pepper), as grown and distributed in quantity for field and garden crop production, are not considered in the category of nursery stock, their movement interstate involves much the same elements of risk as the woody plants of nursery origin commonly designated as nursery stock. Because of this largely artificial distinction, it has been a usual custom to treat these vegetable plants as a separate quarantine subject although the quarantine procedure observed for them closely follows that employed for the nursery stock proper.

In nearly all States the restrictions and requirements placed on vegetable transplant production are established with a view to avoiding pest dissemination within the State itself, and the inspection and certification procedures involved are in general accepted as providing satisfactory protection by other States. Because transplants can be quickly and universally grown, and can be readily distributed in channels outside of quarantine control, this regulatory supervision over commercial production at source represents about the best practicable service that quarantines can render. The effectiveness of these methods is largely dependent on the extent to which this control system is supported by individual growers and by the general public.

SEED SWEETPOTATOES AND PLANTS -- Outstanding in the vegetable transplant category are the so-called slips or draws of sweetpotato. While sweetpotatoes and these rooted cuttings are generally regulated to prevent spread of the sweetpotato weevil (*Cylas formicarius*) several States also take cognizance of diseases of this crop in their restrictions on interstate movement. Alabama (Reg. 2; June 1, 1948) requires a certificate from the State of origin on seed sweetpotatoes and sweetpotato plants entering the State. Oklahoma (Reg. No. 20; 1944) makes this certificate requirement for sweetpotato plants, but provides as well for inspection on arrival. South Carolina (Sweetpotato Regs.; March 1449) requires corrosive sublimate soak for seed sweetpotatoes and disinfection of frames and bedding with formaldehyde in the State's propagation procedure, and demands this also for out-of-State seed stock, which must be certified and entered under a permit-tag arrangement. Arkansas (Rule 18; 1937) also depends on the State-of-origin certificate and the permit-tag system for sweetpotato plants, and allows their entry only from other States where weevil is not known. Mississippi (Rule 23B, amended; Oct. 8, 1941), and Missouri (Reg. No. 11(G); April 15, 1946) also require the State-of-origin certificate and the permit-tag feature for seed sweetpotatoes and sweetpotato plants. Georgia (Sweetpotato Regs.; June 1, 1949) and Louisiana (Certified Seed Reg. No. 9; April 1, 1949) adopted a similar certificate and permit system, but go further to establish standards for planting stock production within the State and then require seed sweetpotatoes or plants entering from outside to meet these standards.

It will be noted that all these restrictions and requirements are essentially of the nursery stock type, following the nursery stock plan in slightly modified or accentuated form. The quarantines by Kansas (Quar. No. 9; March 15, 1947) and Texas (Quar. Procl. No. 48 A; March 7, 1949) are more definitely of true interstate character. In both these an embargo is placed on seed sweetpotatoes and plants (and in the case of Texas on all sweetpotatoes) coming from the ten States where the internal cork disease (virus) is known to exist, in order to prevent the introduction of this new and undesirable sweetpotato trouble. In Kansas the whole State is thus given quarantine protection; the protected part of Texas comprises 144 counties.

These two quarantines should probably be looked upon as precautionary measures, representing the most effective protective effort the State could make in the absence of adequate knowledge on distribution, nature, host, and symptomatic relations of the disease, or of its potential damage, means of spread, or amenability to inspection and certification methods. This situation well illustrates a frequent quarantine dilemma -- a sincere urge to serve the public welfare by taking the most hopeful course of action, but without the comforting assurance that this will duly accomplish the purpose or even that it will prove of any real benefit.

SEEDLING VEGETABLE TRANSPLANTS -- Seedling transplants are also an item of considerable importance in interstate trade, especially those of tomato, cabbage, onion, and pepper. For the most part these move freely interstate with or without certification by the State of origin. A few States however impose certain restrictions on interstate movement as a protection measure against disease in general.

Arkansas (Rule 18a; Dec. 22, 1941) allows entry of cabbage, onion, and tomato plants under a permit arrangement based on field inspection and certification by the State of origin; and Oklahoma (Seed Law, Reg. 20; 1944) follows the same procedure for plants of cabbage, onion, pepper, and tomato. A similar control is exercised by South Carolina (Regs. T.1, T2, T3, C2, C3; Jan. 1, 1924) over cabbage and tomato plants entering the State.

ONION, SHALLOT, DISEASES -- Louisiana regulates the production of onion bulbs and seeds (Cert. Seed Reg. 7; Aug. 15, 1945) and shallot seed (Cert. Seed Reg. 11; Aug. 15, 1949) within the State and demands the same certification procedure for these products entering from other States. These measures are intended to keep planting stocks free from mildew, smut, pink root, yellow dwarf, and mosaic.

PEPPER BACTERIAL CANKER, (Xanthomonas vesicatoria) -- Puerto Rico (Quar. No. 3, revised; July 30, 1948) attempts to prevent establishment of this disease in the Island's cultures by a requirement of disinfection at origin for tomato and pepper seeds, this treatment to be verified by an accompanying certificate.

SUGARCANE DISEASES -- Louisiana (Sugarcane Quar.; Oct. 15, 1928) and Hawaii (Reg. 1.1, revised; Aug. 14, 1947) have attempted to prevent the introduction of insect and disease pests into their important sugarcane cultures by prohibiting the movement of canes or parts thereof likely to carry pests, except under a permit system which can set up effective safeguards against pest entry and, at the same time, avoid artibrary and useless interference with normal commerce and the proper development of the sugar industry (See also under Grasses).

RICE SEED DISEASES -- Louisiana (Cert. Seed Reg. No. 10; Aug. 24, 1949) has set up standards and procedures for the production of quality rice seed within the State. Incidental to this certified seed program the State sets up requirements for rice seed introduction from elsewhere, based on what is essentially certification by the State of origin. Since neither the local program nor the exterior requirements refer to specific rice diseases, the inclusion of this measure here is questionable.

STRAWBERRY, GENERAL DISEASES -- Three States, Alabama (Nurs. Regs., revised; Sept. 24, 1943); Arizona (Quar. Order No. 10, Reg. 1; Jan. 25, 1946); and Kansas (Nurs. Stock Rules and Regs.; June 10, 1948), make a special feature of strawberry plants, largely, it may be surmised, because they fall outside the woody-stemmed plants customarily classed as nursery stock. The requirements for these plants are of the usual nursery-stock character involving certification at point of origin as to disease freedom, and in the case of Kansas evidence of a double field inspection if so listed for sale.

STRAWBERRY RED STELE, (Phytophthora fragariae) -- Three States, Kansas (Nurs. Stock Rules and Regs.; July 1, 1932); Michigan (Reg. 609; Aug. 29, 1946); and New Jersey (Regulations, Feb. 14, 1939) have taken special cognizance of this strawberry trouble, and require the State-of-origin certificate to assure freedom from this fungus.

POTATOES: SEED POTATOES, VARIOUS DISEASES -- The development of seed potato certification in this country since about 1914 has been spectacular. It is a success story of truly epic quality, since the movement has nearly doubled the national per-acre yield in this period. It is particularly noteworthy that this astonishing result has been achieved with a minimum of resort to quarantine and regulatory methods; it has been accomplished largely by helpful technical guidance, cooperative enterprise, and on the part of the State by official service rather than by legal compulsion. In this respect it serves as a sound and healthy model for many other future problems.

The general procedure followed over and over in various States involves freeing a selected seed lot from virus diseases, grading, packing, and storing the product according to acceptable high standards, and distributing it under certificates establishing its seed quality. Although this certification has been variously sponsored by State agencies, by associations, by growers' cooperatives, and even by private firms, experience has bred a widespread confidence in the certification plan, and "certified seed" is directly or indirectly utilized for planting about 75 percent of the country's potato crop.

A great bulk of this certified seed production, as well as much uncertified stock, moves freely in interstate commerce because of the faith of growers and regulatory authorities alike in the over-all effectiveness of the certification system. Quarantine actions for certain specific potato diseases are noted below, but only a few States have considered it necessary to regulate the entry of seed potatoes as a general protection against potato diseases. These are Alabama (Reg. No. 3; Oct. 9, 1941); Arkansas (Rule 70, amended; Dec. 22, 1941); Idaho (Quar. No. 29; Jan. 31, 1944); Louisiana (Irish seed potato Reg., revised; Oct. 15, 1944); Mississippi (Rule 60, amended; May 9, 1938); Oklahoma (Quar. Order No. 5, revised; Jan. 1, 1944); and South Carolina (Reg. 16 Q, revised; Jan. 9, 1939).

The measures of all these States depend on certification by the State of origin; all but Mississippi and Idaho stipulate sealed and tagged containers; Arkansas, Idaho, and Louisiana restrict entry for seed purposes to certified stocks; inspection on arrival is emphasized by Louisiana and Oklahoma; Idaho regulations specifically exclude all seed lots with ring rot; Louisiana and Alabama prescribe tolerances to be met for all diseases, and Oklahoma sets up tolerances for diseases detectible by tuber inspection; otherwise, the disease inspection standards of the producing States are accepted.

POTATO BACTERIAL RING ROT (Corynebacterium sepedonicum) -- That the sudden appearance and rapid spread of this troublesome potato disease was not accompanied by numerous costly and disruptive quarantines is perhaps attributable to a general confidence in the national system of disease control which has been so outstandingly successful for this crop over the years. While ring rot has been a difficult local problem, particularly in seed potato production, only a few States have attempted to strengthen their control efforts by quarantine methods of interstate character, and in these cases a special objective is apparent.

Idaho (Quar. Order No. 29; Jan. 31, 1944) excludes seed potatoes affected by ring rot; Minnesota (Quar. No. 7; May 15, 1946) aims to preserve certain areas in the State as a seed potato source free from ring rot; Texas (Quar. Procl. No. 40-E; Dec. 5, 1946) likewise would keep an important potato area free from the disease; and Washington (Quar. Order No. 31; March 18, 1948) depends on the seed certification system to keep ring rot out of seed potatoes coming in from other States.

POTATO GOLDEN NEMATODE, Heterodera rostochiensis -- Because of its destructive character and persistence in soil, the golden nematode presents a definite threat to the widespread and nationally important potato industry of this country. However, the cooperative regulatory and control program undertaken by the Federal Department of Agriculture and New York State appears to have been generally accepted as protecting the potato interests of other States, and quarantine measures have been taken only by three New England States, largely to enable them to prevent irregular or unauthorized truck shipments of potatoes from the only known infested area, which is located in Long Island. These special measures by Maine (Executive Order No. 48; June 20, 1947); New Hampshire (Quar. Order No. 1; Aug. 15, 1947); and Vermont (Quar. No. 5; Aug. 25, 1947) all prohibit the movement of potatoes from the infested area into or through the State.

POTATO LATE BLIGHT, (Phytophthora infestans) -- In recent years evidence has accumulated emphasizing the role of potato tubers in carrying over the late blight fungus. While important enough in areas subject to blight or in favorable blight seasons, this carry-over may be a critical factor in generally blight-free areas or in years with low blight incidence. Seed potato certification standards normally attempt to keep late blight tuber rot out of certified stocks, and this procedure apparently satisfies most State requirements.

Texas is the only State which has imposed special late blight restrictions (Quar. Procl. No. 40-E; Dec. 5, 1946). Seed potatoes entering the State are required to have a certificate by the State of origin, establishing freedom from late blight (also bacterial ring rot and tuber moth), when destined to three counties in the State for which protection is desired.

POTATO, ROOT KNOT NEMATODE, Heterodera marioni (Meloidogyne sp.) -- Since this nematode is said not to occur within the State of Utah, a State quarantine (Quar. No. 2, revised; June 10, 1947) requires a State certificate of freedom from this root pest in connection with all potatoes and tomato plants from eight Southern and Western States and the Territory of Hawaii.

TOBACCO ETCH (Virus - Marmor erodens var. vulgare) -- A Georgia quarantine (Quar. No. 8; Nov. 15, 1948) attempts to protect the tobacco culture of the State from this virus disease by prohibiting the movement of tobacco plants from two counties within the State where infection exists, and into Georgia from three Florida counties. This prohibition is safeguarded by requiring certification by the Florida Plant Board of tobacco plants from elsewhere in Florida.

TOBACCO BLUE MOLD (Peronospora tabacina) -- The readiness with which this fungus is carried northward each spring has discouraged any attempt to use quarantine methods in the numerous sections of the East where tobacco culture is prominent. The existence of effective control methods in the critical seedbed stage also serves to weaken any thought of resort to quarantine measures of dubious worth. However, the special importance of the tobacco crop to the Territory of Puerto Rico and the natural sea protection enjoyed by the Island appear to justify attempts to exclude this disease from mainland sources, and an insular quarantine (P. R. Quar. No. 6; revised; July 30, 1948) is in effect requiring all tobacco seed of mainland origin to be routed through the insular quarantine service and to assure that such seed is disinfected either at source or on arrival; the quarantine also prohibits movement into Puerto Rico of shade cloth previously used on mainland tobacco fields.

TOMATO BACTERIAL CANKER -- See under Pepper

TOMATO ROOT KNOT NEMATODE (Heterodera marioni) -- To protect six counties from the introduction and spread of root-knot nematode Virginia has imposed a quarantine (Quar. No. 6; May 1, 1940) providing that all tomato plants moving into this six-county area from elsewhere in the State or from other States shall be accompanied by a State certificate establishing their freedom from visible root knot and from other destructive insects and plant diseases. This quarantine is recognizable as merely a special case in the general plan of nursery stock procedure.

GENERAL COMMENT

In reviewing this sketchy summary of the present status of State quarantines affecting interstate commerce, the interest of the plant pathologist will doubtless have been aroused by several features of general import. In the first place, it will be noted that relatively few of these interstate quarantines aim at true areal protection; the majority simply attempt to reduce the chances of pathogen introduction or endeavor to keep individual plantings or soil tracts free from the intruder.

It is strikingly apparent also that a great number of these measures are merely extensions or special cases of the common procedure pattern adopted for regulating nursery stock. Many of them are actually set forth in State nursery stock regulations, and if the arbitrary conception of "nursery stock" were broadened to comprise a wider range of propagating materials than the woody plants generally included, more of these quarantines would undoubtedly fall readliy into this category where, in spite of legalistic custom, they truly belong.

A third point which deserves mention is the tendency to add interstate features to the State's own internal program set up under regulation for local disease control. In a number of cases the interstate element in these measures is obviously tagged on in vague and indefinite terms as a rounding out of the protective scheme, but is not given the care and attention a true interstate quarantine would seem to demand.

Again, mention has been made in several instances of the helpful activity of the plant board system in the interstate quarantine field. The evidence from this study indicates that the several plant boards have exerted a gratifying influence in bringing about agreement not only in the terms but also in the basic conceptions of measures proposed among State groups. This trend toward unification of viewpoint and procedure is particularly evident in recent quarantine promulgations, and with the helpful operation of the Plant Board organization it can be expected to exhibit itself increasingly in future problems affecting a number of States.

Still another feature will be observed by the pathologist in this quarantine summary -- the pronounced patchwork effect of our interstate quarantine measures. Even with due allowance made for regional, climatic, and crop differences, and for legal and financial limitations among the States, there is still observable a certain inconsistency in the application of quarantine methods to the same problem by individual States. We can only regard this irregularity of front toward a common enemy as evidence of the newness and incompleteness of the quarantine system which the Nation is in process of developing. It may be expected that time and experience will eventually bring into the picture a unity so obviously lacking at this stage of progress.

From the plant pathologist's standpoint perhaps the most significant feature brought out in this summary is the unfortunate necessity of attempting quarantine action before adequate knowledge is available on which sound procedure may be confidently based. Lack of vital information has plagued quarantine effort from the very beginning, and it still vexes the quarantine planner at every step. It cannot be considered his sole responsibility, however. The current conception of a quarantine regards it as a community effort to which all who can should contribute. On this view the plant pathologist is called on to participate along with the other groups and elements concerned. If quarantine methods are to be helpfully utilized in the war waged by humanity against crop pests, the pathologist's aid is indispensable not only in furnishing the facts and information so urgently needed for success, but also, by virtue of his special viewpoint and experience, in actively helping to plan a healthy future course for the quarantine movement.

DIVISION OF DOMESTIC PLANT QUARANTINES, BUREAU OF ENTOMOLOGY AND PLANT QUARANTINE, AGRICULTURAL RESEARCH ADMINISTRATION, UNITED STATES DEPARTMENT OF AGRICULTURE

HISTORY OF BOTANY AND PLANT PATHOLOGY AT ALABAMA POLYTECHNIC INSTITUTE

James A. Lyle

Work in botany and plant pathology was initiated at the Alabama Polytechnic Institution in 1883. In that year P. H. Mell was appointed as botanist of the Alabama Agricultural Experiment Station, serving in that capacity until September 1902. He was author of bulletins on the woods, grasses, and flora of this State.

Although the department of botany and plant pathology at the Alabama Polytechnic Institute has always been primarily a teaching department, some noteworthy contributions have been made in research. Several notable men have been associated with the department. The most outstanding of these was George F. Atkinson, who was appointed late in 1889 to fill the just created position of biologist. He spent only three years at Auburn, but he accomplished more in that length of time than any other member of the department before or since his time. Atkinson's publications covered a variety of subjects ranging from pure mycology to physiological disturbances and even entomological problems.

From the standpoint of Alabama's agriculture Atkinson's most important work was on cotton diseases. He was the first to show conclusively that the "rust" of cotton could be corrected by applications of potash fertilizers. This work, published in 1892, resulted in a revision of fertilizer practices in Alabama, and probably did more than any other one thing to improve yields of cotton in the South at that time. Atkinson also made major contributions to our knowledge of other cotton diseases. He isolated and named the fungus causing Fusarium wilt. He published three experiment station bulletins describing the root-knot nematode disease, leaf blights, damping-off, anthracnose, angular leafspot, and "areolate mildew". Atkinson probably contributed more to our knowledge of cotton diseases than any other man before or since his time.

Atkinson was succeeded in 1892 by J. M. Stedman, who published papers on boll rots of cotton and on blights of fruit trees. Stedman held this position until 1895, when he in turn was succeeded by L. M. Underwood, who served as biologist for one year.

F. S. Earle was appointed as biologist in August, 1896. He and Underwood published a paper designated as "A Preliminary List of Alabama Fungi." Earle later published an article on the flora of Alabama. He resigned in 1901, and was succeeded by E. Mead Wilcox. Wilcox remained until July 1, 1908. During his tenure at this institution, he published several bulletins on diseases of oak, apple, cherry, peach, pear, plum, and sweetpotato.

F. E. Lloyd was appointed botanist and plant physiologist on November 1, 1908. He published papers on coloring of persimmons, leaf water and stomatal movement of cotton, and other physiological material. He also wrote a monograph on guayule. Lloyd resigned on September 1, 1912.

F. A. Wolf served as plant pathologist of the Experiment Station from 1911 until January 1, 1916. During this period, he wrote many articles on the diseases of apple, citrus, cotton, eggplant, peanut, peach, rose, and walnut. Wolf's work on Cercospora leafspot of peanut was another landmark. He described in detail the life history of Cercospora personata. It was more than 20 years before any other significant contributions were made to our knowledge of this disease.

J. S. Caldwell succeeded Lloyd as botanist and plant physiologist on September 9, 1912, and remained at Auburn until January 1, 1916. Among articles published while here was the one he wrote on natural wilting of plants.

W. J. Robbins was botanist and plant physiologist from February, 1916, to July, 1917. During his stay he published an article on the cause of the disappearance of cumarin, vanillin, pyridine, and quinoline in the soil.

On September 1, 1916, G. L. Peltier was appointed plant pathologist to succeed Wolf. Peltier's work was devoted mainly to citrus canker. He published several papers on various phases of this disease. Peltier resigned April 1, 1920.

On September 1, 1917, W. A. Gardner was appointed to succeed Robbins, and on July 1, 1918, was made head of the Department of Botany. Gardner published papers primarily on soil toxins.

Robert Stratton was assistant professor of botany from January 1, 1918, to July 1, 1920.

On September 15, 1919, E. F. Hopkins was appointed associate plant pathologist to devote his time to the study of diseases of cereal and forage crops. He resigned on April 1, 1920.

Peltier and Hopkins were succeeded by A. F. Thiel, who held the position of acting plant pathologist from April 1 to November 15, 1920.

G. R. Johnstone was assistant professor of botany from September 1, 1920, to July 1, 1923.

Johnstone's field was that of plant physiology, and while at this institution he worked on a physiological study of the sweetpotato. In conjunction with E. R. Miller and C. A. Cary, he published on the poisonous plants of Alabama.

A. H. W. Povah was appointed plant pathologist on July 1, 1921, which position he held until he resigned in April, 1922.

L. E. Miles accepted the position of associate plant pathologist on September 1, 1922, a position which he held until July 1, 1924, when he transferred to full-time extension work. He published papers on the dry-rot of buildings and stored construction materials.

C. C. Zeliff was assistant professor of botany from July 1, 1922, to July 1, 1923.

M. L. Blain was appointed associate plant pathologist on July 1, 1924. M. L. Palmer was appointed at this time as assistant in botany from July 1, 1924, through July 1, 1927. On July 1, 1927, G. L. Fick was appointed to fill the vacancy created by the resignation of Palmer. In 1928 Blain resigned. Research projects included studies of the physiology of the satsuma orange, the phyisology and diseases of sweetpotatoes, pecan scab, and soil toxins.

In 1929, J. L. Seal was appointed as associate plant pathologist and G. L. Fick was advanced to the rank of assistant botanist. E. V. Smith was appointed as assistant in botany in 1931. From 1929 to 1932 research projects were devoted to a continuation of the sweetpotato and satsuma studies, together with studies on the diseases of winter pea and vetch, and the life history of nutgrass. With the resignation of Gardner in 1932, J. L. Seal was made botanist of the Experiment Station and head of the Department of Botany and Plant Pathology.

The staff was unchanged from 1932 to 1936. During this period the research projects included studies of small grain, winter pea, and vetch diseases, and life histories of nutgrass and wild garlic and their control.

In 1936, at the untimely death of G. L. Fick, E. V. Smith was appointed as associate botanist. In this same year J. R. Jackson was appointed as assistant botanist and H. M. Darling as assistant plant pathologist (cooperating with the State Department of Agriculture). Darling was located at the Gulf Coast Substation, near Fairhope, Alabama, to work primarily on Irish potato diseases.

Darling resigned in 1941 and was replaced by T. R. Wright. T. H. King was appointed as an instructor in botany and plant pathology on September 15, 1941. In May, 1942, he was granted a leave of absence and started service in the U. S. Army. D. A. Preston was appointed to fill the vacancy. In 1944 Coyt Wilson, who had served as assistant in botany from 1938 until 1941, was appointed as assistant plant pathologist, and E. V. Smith became assistant dean and director in the College of Agriculture the same year. R. L. Self was appointed as instructor in botany and plant pathology from October, 1945, to June, 1946, H. E. Brewer was appointed as assistant professor of botany in July, 1946. Brewer filled the vacancy created by the termination of T. H. King's leave of absence. R. B. Stevens was appointed as associate professor of botany in July, 1946. T. R. Wright and R. B. Stevens resigned in June, 1947. J. R. Jackson resigned in September, 1947. From 1936 to 1947 research studies were devoted to cotton seed treatment tests, peanut, winter pea, vetch, and Irish potato diseases, the life histories and control of Cherokee rose, nutgrass, Bermuda grass, wild garlic, and wild onion, effect of pasture improvement on weed populations, plants poisonous to livestock, and plant food for fish and farm pond management. Numerous articles were published in scientific journals and as Experiment Station circulars and bulletins.

H. E. Brewer became associate botanist in July, 1947. In September, 1947, K. H. Garren was appointed as associate professor of botany, and D. E. Davis and H. S. Ward, Jr., were appointed as assistant professors of botany. J. A. Lyle was appointed assistant plant pathologist on October 15, 1947. Brewer resigned in January, 1949. J. F. Ferry was appointed as associate professor of botany, in February, 1949, and R. L. Self was appointed to a similar position in April, 1949. W. P. Orr was appointed as graduate assistant in botany in March, 1949.

At the present time research programs are devoted to investigations on the diseases of peanuts, forage, legume, and grain crops, and vegetables. In the peanut disease program, a cooperative arrangement has been developed with the Department of Zoology-Entomology. Major emphasis is being placed on the development of practices that will control diseases and insects in one operation. The work on forage crops, legumes, and grain crops is coordinated with the plant breeding work done by the Department of Agronomy and Soils. Studies on vegetable diseases, in recent years, have been limited to field trials of fungicides on potatoes and tomatoes. This project is being expanded to include studies on the epidemiology and control of the major diseases of pepper, tomato, potato, sweetpotato, cabbage, bean, peach and strawberry. A limited amount of work is being devoted to forest and ornamental diseases.

UNITED STATES DEPARTMENT OF AGRICULTURE

Plant pathologists of the United States Department of Agriculture have obtained research data for several publications, in whole or in part, in Alabama.

A. L. Smith has been stationed at Alabama Polytechnic Institute since 1946. His research is devoted to breeding cotton for disease resistance and to soil fumigation for control of cotton diseases. He works cooperatively with the Department of Agronomy and Soils.

D. L. Gill has been stationed at Spring Hill, Alabama, since 1946. While there he has been working on the diseases of ornamental plants, particularly diseases of azaleas and camellias.

ALABAMA POLYTECHNIC INSTITUTE, AUBURN

A BRIEF HISTORY OF THE DEVELOPMENT OF RESEARCH IN PLANT PATHOLOGY IN ARKANSAS

V. H. Young

INTRODUCTION

Although the University of Arkansas was founded in 1871, there is no evidence from the available records that either teaching or research in the field of Plant Pathology was carried out prior to the establishment of the Arkansas Agricultural Experiment Station under the Hatch Act in 1887. Records show that a limited amount of teaching and research in Plant Pathology were carried out in the Department of Horticulture during the period 1887-1909. The Department of Plant Pathology was established in 1909.

RESEARCH IN PLANT PATHOLOGY PRIOR TO 1909

The period 1887-1909 seems to have been largely a period of observation and exploration so far as plant disease research was concerned. At least three early members of the staff of the Department of Horticulture, Professors J. T. Stinson, Ernest Walker, and J. Lee Hewitt, reported in the bulletins of the Experiment Station on the presence of such diseases as apple scab, apple bitter rot, apple cedar rust, pear blight, apple sooty blotch, apple blotch, downy mildew of grapes, black rot of grapes and strawberry leaf blight (apparently largely Mycosphaerella leaf spot although leaf scorch seems also to have been present). During this period, large numbers of apple, grape, and strawberry varieties were planted in variety tests and the notes made regarding varietal resistance and susceptibility are of historical interest. In one of the first bulletins of the Arkansas Experiment Station, Dr. Wm. Trelease is listed as "Consulting Botanist." It seems uncertain that Dr. Trelease was ever actually in residence.

In 1896, Stinson reports submitting a new apple disease to L. H. Bailey and B. T. Galloway. The former is reported to have suggested the name "Skin Blotch" for this trouble. Galloway identified the organism present as Leptothyrium pomi. It seems evident that "Sooty Blotch" was the disease under consideration.

During this early period many trials were made of various spray materials including bordeaux mixture and ammoniacal copper carbonate spray. Notes on the control of apple scab, apple bitter rot, downy mildew of grapes, black rot of grapes, and strawberry "leaf blight" are given. Apple spraying on a commercial scale was reported in 1894 and it is apparent that control of fruit diseases by spraying was a well established practice in the State by 1896.

During the period 1887-1909 several other diseases are mentioned casually and mention is also made of the use of copper sulphate dips for control of smut in wheat.

PLANT PATHOLOGY SINCE 1909

The Department of Plant Pathology was established in 1909 as a teaching and research department. From the very start it is apparent that the work of the department was divided among teaching, research, and extension work. In 1917 the Arkansas State Plant Board was established with the Head of the Department of Plant Pathology as an ex-officio member of the Board.

For a brief period during World War I an Extension Plant Pathologist, M. S. Ensign, was hired and on November 1, 1949, Dr. Robert Emge (Ph. D., Illinois) became Extension Plant Pathologist. In the meanwhile all of the normal activities of an Extension Plant Pathologist have been carried out by the staff of the Department of Plant Pathology. This work has been valuable to the Department since it brought the staff more closely in contact with the economic plant disease problems of the State.

RESEARCH PROGRAM 1909-1950

As previously noted, the period prior to 1909 was one of observation and exploration with little original research in Plant Pathology. After 1909 there was a period which might be called a "period of orientation." The staff members for at least four or five years were primarily trained in Horticulture with little graduate training in Plant Pathology. Several of these men remained only one or two years and seem to have left little or nothing behind in the way of published research.

Professor J. Lee Hewitt, B.S., Missouri, was for several years prior to 1909 a member of the staff of the Department of Horticulture. In 1909 he became the first Professor of Plant Pathology and the first Head of the Department of Plant Pathology. It appears that he was forced by the demands of the Northwest Arkansas apple growers to devote much of his time to a study of apple diseases. As early as 1911 he was joint author with the Entomologist of a publication dealing with the diseases and insects of the apple. Later he published work on apple spraying and on the fireblight disease in Arkansas. In 1913 Hewitt and Truax published the results of their first studies of "Apple Measles", a disease whose etiology still remains comparatively obscure, although Dunegan and Isely showed that at least a part of what Hewitt had called "Measles" was the result of oviposition punctures made by certain leaf hopper species. Hewitt's work on "Apple Measles" is perhaps his most important contribution to our knowledge of plant diseases. In 1912 Hewitt also reported briefly on "Rice Blight" now known as "Straighthead" which Tisdale later showed to be of physiogenic origin.

During the period from 1909-1917 when J. Lee Hewitt was head of the Department of Plant Pathology several young men were associated with the Department for brief periods. Ashleigh P. Boles, B.S., Arkansas 1908, was Adjunct Professor of Plant Pathology 1909-1910 and for many years since has been prominent in the Agricultural Service of the Missouri Pacific Railroad. John S. Stahl was Adjunct Professor during the year 1910-1911 and was succeeded by Harold E. Stevans, B.S., Kentucky State, M.S., Illinois, who was Adjunct Professor during the year 1911-1912. He was followed by Hartley E. Truax, Instructor of Plant Pathology 1912-1913.

In 1913 Walter S. Fields, B.S., Michigan Agricultural College, became Instructor of Plant Pathology and in 1916 he became Assistant Professor of Pathology. He resigned in 1918. All of the above listed men were apparently young and just starting their careers. Generally speaking their time at the Arkansas Experiment Station was too short to allow them to complete much in the way of research.

Dr. John A. Elliott, A.B., Fairmont College, A.M., Kansas, Ph. D., University of Illinois, came to the headship of the department in 1917, succeeding Hewitt who went to the employ of the Arkansas State Plant Board. Elliott was the first well-trained Plant Pathologist to be employed by the University. His work on the genus Alternaria prior to his arrival in Arkansas is recognized as an important contribution to our knowledge of this important genus of plant pathogens. Elliott's training under F. L. Stevens and others at Illinois had prepared him for a long and useful career in Plant Pathology which was cut short by his untimely and tragic death at the height of his career early in January 1923.

During the five and a half years that Elliott was Plant Pathologist of the Arkansas Agricultural Experiment Station, he was interested principally in diseases of cotton and tomatoes. Elliott applied himself principally to the control of angular leaf spot, seedling blights, and Fusarium wilt. He was one of the pioneers in cottonseed treatment research and showed conclusively that angular leaf spot can be controlled on a commercial basis by the sulfuric acid delinting method.

Having been well-trained in Mycology under Stevens, Dr. Elliott was greatly interested in discovery of new disease-producing organisms. The Ascochyta disease of cotton which he first reported in this country and which under the favorable weather conditions that existed for a few years, caused serious local damage, interested him greatly. His work on cotton is summarized in two bulletins entitled "Arkansas Cotton Diseases" and "A New Ascochyta Disease of Cotton."

During his brief time at Arkansas, Elliott selected and developed several wilt-resistant tomato strains which were grown and highly regarded by a number of Arkansas tomato growers long after his death. This work was summarized in his Bulletin 194, "Tomato Wilt and Its Control in Arkansas."

At the time of his death Elliott was engaged in a study of the organism causing black rot of the sweetpotato. His careful studies of the evanescent asci of the pathogen led him to the conclusion that the pycnidia of Sphaeronema fimbriata were in reality perithecia and that what had for so many years been considered to be conidia were in reality ascospores. That Elliott's conclusions were sound is attested to by the fact that Ceratostomella fimbriata Elliott is now everywhere recognized as the correct name for the black rot of sweetpotato pathogen.

A year after J. A. Elliott took charge of the Department of Plant Pathology Harry Robert Rosen (B.S., Pennsylvania State College, M.S., University of Wisconsin) joined the staff with the rank of Assistant Professor. During the year 1921-1922, Professor Rosen was on leave of absence at Washington University, St. Louis, where he completed the work for his Ph. D. under Dr. B. M. Duggar.

With service at the Arkansas Station from 1918 up to the present, Dr. Rosen has more than thirty years with the Department, thus exceeding by several years any other member of the Plant Pathology staff.

During this long period Professor Rosen has naturally interested himself in many phases of Plant Pathological research. During the first ten years at Arkansas his titles include two publications on the Bacterial Stalk Rot of Corn, A Bacterial Disease of Foxtail (dissertation for the doctorate), two bulletins on the Mosaic Diseases of Sweetpotato and one on the Septoria Glume Blotch of Wheat.

During the next few years, Dr. Rosen worked especially on the fireblight disease of apples and pears. Overwintering of the fireblight bacillus in the beehive and the first clearcut explanation of blossom infection through the stomata-like "nectarthodes" of the apple and pear blossoms were among the highly significant contributions to our knowledge of the fireblight disease. Dr. Rosen's work on fireblight was summarized in numerous shorter journal publications and in four extensive bulletins of the Arkansas Agricultural Experiment Station.

Soon after he came to Arkansas, Rosen became interested in the diseases of oats and other cereals and in the possibility of breeding oats for winter hardiness, rust resistance and as a winter pasture crop. Research along this line has resulted in the release of the Traveler variety of oats which has proven its value particularly in the northern part of the winter oat belt because of its high productivity, winter hardiness, and resistance to all common races of the crown rust organism and to common races of loose and covered smut. Several selections of oats, wheat, and barley, primarily bred for disease resistance, are now in the process of development by him.

In addition to the work outlined above, Professor Rosen has been very much interested in the development of new disease-resistant varieties of roses, one of which, Stephen Foster, a hardy climbing rose, has been released to nurserymen for propagation. Improved fungicides for the control of black spot and powdery mildew of roses are another development from this work.

Some months after the death of Dr. J. A. Elliott, which took place in Washington, D. C. where he was for a brief leave of absence with the Plant Disease Survey, the headship of the department was assumed by V. H. Young, Ph. B., Ph. M., Ph. D., University of Wisconsin. Young came from the University of Idaho where he had spent the five previous years as head of the Department of Botany and Plant Pathology.

Professor Young, like his predecessor, has devoted his attention largely to the diseases of cotton and particularly to the Fusarium wilt -- root knot -- potash hunger disease complex. His first publication presented the results of soil temperature studies of the Fusarium wilt disease of cotton. Later studies dealt with soil moisture relationships (with W. H. Tharp) and with the relation of potash deficiency, fertilizer balance, and varietal resistance to the Fusarium wilt disease of cotton. Much of this work was in cooperation with J. O. Ware, George Janssen, and L. M. Humphrey of the Department of Agronomy, and with W. H. Tharp of the Division of Cotton and Other Fiber Crops and Diseases of the U. S. Department of Agriculture. Other phases of the cotton disease problem, especially cotton seedling blights and their control by cottonseed treatment, have been studied more recently. Minor problems have dealt with grape, apple, and strawberry spraying and with cereal seed treatments.

During the year 1921-1922, Raymond F. Crawford, B.S. and M.S. Iowa State, took H. R. Rosen's place while the latter was on leave for graduate studies and in 1928, Dr. Edgar C. Tullis, A.B. and A.M. Nebraska, Ph. D. Michigan State, was added to the staff with the title of Assistant Professor and Assistant Plant Pathologist. Tullis, who was employed jointly by the University of Arkansas and the Division of Cereal Crops and Diseases of the U. S. Department of Agriculture devoted all of his time to rice diseases. In 1930 Dr. Tullis transferred completely to the U. S. Department of Agriculture but continued to carry on his studies of rice diseases in the Department of Plant Pathology until about 1936 when he was transferred to the Rice Branch Station at Beaumont, Texas. During the time that Dr. Tullis was employed by the Arkansas Experiment Station he discovered both the conidial and ascigerous stages of the organism causing stem rot of rice which had previously been assigned to the genus Sclerotium.

Dr. E. M. Cralley, B.S., McKendree, Ph. D., Wisconsin, came to the department in 1931 in a cooperative arrangement with the U. S. Department of Agriculture but shortly was employed full time by the University. For several years, he devoted himself entirely to diseases of rice, but in more recent years he has divided his time between rice disease studies and diseases of alfalfa and soybeans. From December 1946 to February 1948 Dr. Cralley was employed by the U. S. Army to study agricultural problems, especially those connected with rice-growing in Japan and Korea. He returned to the Plant Pathology Department in 1948 with the rank of Professor and Plant Pathologist.

Dr. Cralley was one of the first in this country to demonstrate the value of rice seed treatments for the control of rice seedling diseases and as a result of his work a substantial percentage of the rice sown in Arkansas at present is treated. Control of stem rot of rice through cultural practices, relation of rice fertilization to disease control, the development of rice varieties resistant to disease, and various other rice disease problems have engaged his attention since he came to the Arkansas Station.

Since returning from Korea Dr. Cralley has devoted part of his attention to the "White Tip" disease of rice. Recently he has shown that this disease is caused by seed-borne nematodes which develop in the terminal bud of the rice plant and produce the typical "white tip" symptoms. Seed treatment studies designed to control this disease are a part of the current rice disease program.

The importance of alfalfa in Arkansas as a crop which is to be processed in dehydrating plants has brought the problem of the longevity of alfalfa plantings to the fore. The failure of alfalfa stands, especially in the Eastern Delta area of Arkansas where the principal dehydrating plants are located, threatens to wipe out a prosperous industry unless these problems are solved. Much of Dr. Cralley's time is now being devoted to this important problem.

Dr. Leslie M. Weetman, A. B. Simpon, M.S. and Ph. D. Iowa State, was a member of the Plant Pathology staff during the period 1936-1942. Dr. Weetman, whose training was largely in Genetics and Plant Breeding, was engaged almost entirely in a cooperative project with Prof. H. R. Rosen designed to develop better disease resistant varieties of oats. This work has been considered previously in connection with the discussion of Dr. Rosen's research. Dr. S. B. Locke, B.S. Oregon State, M.S. and Ph. D. Wisconsin, came to the Department of Plant Pathology in 1939 to initiate a program of vegetable disease research. He was with the Arkansas Station from 1939-1943 and left the department to engage in emergency war work in the U. S. Department of Agriculture. Dr. Locke studied primarily resistance to early blight and Septoria leaf spot of tomatoes and succeeded in securing a number of promising hybrids with South American species of Lycopersicon which showed marked resistance to these diseases. Other crosses which Dr. Locke developed showed promise from the point of view of resistance to the Fusarium wilt of the tomato. Control of tomato leaf spots through use of fungicidal applications was also a part of the tomato disease program upon which he was working.

From 1943-1945 Dr. J. R. Shay, B.S. Arkansas, M.S. and Ph. D. Wisconsin, continued Dr. Locke's work with tomato diseases and also began a study of spinach diseases. One important result of the latter work was a demonstration of the fact that much of what had been called cold weather injury to spinach was in reality "Spinach Blight" caused by one or more strains of the cucumber mosaic virus and that the Old Dominion and Virginia Savoy varieties of spinach possesses a high degree of resistance to several of the strains of this virus. Shay also secured some very interesting preliminary results with the use of eradicant sprays for the control of black rot of grapes.

Dr. Joseph P. Fulton, A.B. Wabash, M.A. and Ph. D. Illinois, succeeded Dr. Shay in 1947. Dr. Fulton has been especially interested in the virus diseases of spinach and other vegetables and in tomato diseases. His discovery of a strain of cucumber mosaic virus capable of attacking blight resistant varieties of spinach in a highly destructive manner demonstrates that the spinach blight problem may become much more severe than it is at present. Recently Dr. Fulton has published the results of his preliminary studies of the spinach virus problem and has with Neil Fulton a report of a tomato root rot caused by the pathogen of buckeye rot of tomato. Dr. Fulton is also studying the virus diseases of strawberries and the red stele disease of strawberries.

Dr. Curtis L. Mason, B.S. and M.S. Texas A. & M. and Ph. D. Illinois, came to the Department with the rank of Assistant Professor and Assistant Pathologist in 1948, Dr. Mason's research at present is very largely confined to a study of bacterial spot and brown rot of peaches and their control by improved spraying techniques. Among the new materials being tried by Mason are calcium and sodium hypochlorite which in preliminary trials reported in 1949 seemed to offer considerable promise for use in the peach spray schedule.

Dr. Albert Miller, B.S., M.S., and Ph. D. Cornell, who was Instructor in Plant Pathology and Entomology from 1938-1940, and Mr. Neil D. Fulton, B.S. Arkansas, who joined the staff in 1949, were hired primarily as members of the teaching staff. Dr. Robert G. Emge, Ph. D. Illinois, was hired as Extension Specialist in Plant Pathology in 1949. Although Dr. Emge is not, strictly speaking, a member of the staff of the Department of Plant Pathology, he continues to interest himself so far as time permits, in research matters, and is already proving his value to our department through his field contacts with practical problems which he encounters throughout the State. Dr. T. C. Liu, Ph. D., Oregon State, a native of China, joined the staff in 1942 and continued for approximately three years as research assistant in connection with studies of the cotton wilt disease.

Besides the members of the Plant Pathology staff enumerated above there have been considerable numbers of graduate and undergraduate students who have gone on to a career in Plant Pathology elsewhere. Some but not all of these men have served either as graduate or undergraduate research assistants in the Department of Plant Pathology. Among those who have either Bachelor's or Master's degrees or both from this institution may be listed the following:

John C. Dunegan, M.S., Arkansas, now Senior Pathologist, U. S. Department of Agriculture
A. B. Groves, M.S., Arkansas, now Plant Pathologist Virginia Experiment Station
John R. Large, M.S., Arkansas, Assistant Plant Pathologist, U. S. Department of Agriculture
Albert L. Smith, M.S., Arkansas, Pathologist, U. S. Department of Agriculture
Luther Shaw, M.S., Arkansas, Agronomist, U. S. Department of Agriculture
A. B. Wiles, M.S., Arkansas, Graduate Student, University of Wisconsin
Ollie D. Burke, B.S.E., Arkansas, Extension Plant Pathologist, Pennsylvania
Glenn S. Pound, B.S., Arkansas, Associate Professor, University of Wisconsin
J. Ralph Shay, B.S., Arkansas, Assistant Professor, Purdue University
George W. Bruehl, B.S., Arkansas, Associate Pathologist, U. S. Department of Agriculture
Mannon Gallegly, B.S., Arkansas, Assistant Professor, University of West Virginia
Harlan Smith, B.S., Arkansas, Graduate Student, University of Wisconsin.
James. G. Horsfall, B.S., Arkansas, Director Connecticut Agricultural Experiment Station

Besides the men listed above, who were either employed by the Arkansas Experiment Station or were students at the University of Arkansas, there should be mentioned three members of the staff of the U. S. Department of Agriculture who were stationed at the University of Arkansas in a cooperative relationship with the Department of Plant Pathology.

Mr. John C. Dunegan, now Senior Pathologist, in charge of Deciduous Fruit Disease Investigations, U. S. Department of Agriculture, Beltsville, Maryland, was stationed with the Department of Plant Pathology from 1928-1945. Mr. Dunegan was concerned primarily with apple spraying investigations but found time to investigate a number of fruit diseases, among which may be mentioned bacterial spot disease of stone fruits and rusts of the genus *Prunus*.

E. C. Tullis, now Plant Pathologist, Division of Cereal Crops and Diseases, after leaving the staff of the Department of Plant Pathology in 1930 to join the staff of the U. S. Department of Agriculture, was stationed with the Plant Pathology Department for several years and continued his work with diseases of rice.

W. Hardy Tharp, now Senior Physiologist, Division of Cotton and Other Fiber Crops and Diseases, was stationed at the University of Arkansas from 1936-1950 and carried out cooperative studies on cotton diseases with members of the Plant Pathology Staff during part of this time.

ACTIVITIES OTHER THAN RESEARCH

Although these notes are concerned primarily with the research in Plant Pathology, the record would be incomplete without some mention of other activities of the Plant Pathology Staff. These are discussed here briefly.

Extension Work. Except for a very brief period during World War I there was no Extension Plant Pathologist in Arkansas until Dr. Robert G. Emge came here in November 1949. During this time the staff carried out all of the ordinary functions of an Extension Plant Pathologist which need not be enumerated here.

Arkansas State Plant Board. The regulatory work of the State with respect to nursery stock, seeds, fertilizers, feeds, etc. is in charge of the Arkansas State Plant Board of which the head of the Department of Plant Pathology is an ex-officio member. In this capacity he attends all formal meetings of the Board and acts as a consultant in matters pertaining to plant diseases. He does not, however, take part directly in the regulatory activites of the Board. Since 1924 the present head of the department has also served as secretary of the Board.

Teaching Activities. While not all members of the Experiment Station Staff in Plant Pathology have teaching duties, most of them do some teaching and in recent years between 300 and 400 students have enrolled in classes each year in Plant Pathology. The curriculum of the College of Agriculture requires that every graduate in Agriculture complete the introductory course in Plant Pathology and that in addition he take an advanced course in either Plant Pathology or Entomology. Courses are offered in Diseases of Southern Field Crops and in Diseases of Southern Fruit and Vegetable Crops. At least half of the student body elect an advanced course in Plant Pathology. In recent years many students have elected to take both of the advanced courses in Plant Pathology and the corresponding advanced courses in Entomology. Since a very large part of the graduates in the College of Agriculture become either County Agents or Teachers of Agriculture, it is felt that this program, which provides a limited training in the subject for all students rather than a considerable amount of advanced work for a limited group, best serves the interests of the State.

UNIVERSITY OF ARKANSAS, FAYETTEVILLE

PLANT PATHOLOGY IN NEW JERSEY[1]

C. M. Haenseler

INTRODUCTION

New Jersey is relatively small in area, covering only 8,224 square miles, but this smallness does not restrict either the number or the importance of the plant disease problems that occur within its borders. At the southern end of the State there is a warm, humid coastal plain area with an average of 218 frost-free days. At the northern end there are heavier soils with grassy and wooded slopes rising to 1800 feet above sea level. Here the nights are cool and there are, on the average, only 138 frost-free days a year. Such wide variations in season length, soil type, and topography give New Jersey a great variety of growing conditions, which permits the production of a large variety of economic plant types and complicates the problem of economic disease control.

New Jersey has extensive areas devoted to special crops such as cranberries and blueberries which present disease problems not met with in many other States. Our proximity to large metropolitan centers also adds materially to the plant pathologists' troubles. These nearby markets have encouraged development of numerous intensive truck garden centers with many acres under glass. These truck areas alone grow some half hundred different types of miscellaneous vegetable crops. Other sections, specializing in canning crops, grow many thousands of acres of tomatoes, asparagus, peas, beans, peppers, and spinach. Extensive muck lands, devoted largely to onions, celery, and lettuce, create disease problems peculiar to this particular soil type and cropping system. Tree fruits, both apples and peaches, with their multiplicity of diseases, cover some 39,000 acres. Small fruits, such as raspberries, blackberries, and strawberries, also find their place but on a much smaller scale.

New Jersey has some of the largest nurseries in the country as well as many large greenhouse establishments specializing in roses, orchids, ferns, or miscellaneous ornamentals for the metropolitan trade. This immense field of ornamentals alone presents a long list of disease problems that constantly calls for study and service.

Obviously, large urban centers such as we have in and adjacent to New Jersey mean large investments and consequently intense interest in shade trees, lawns, golf links, public parks, water sheds, and private gardens. All of these add tremendously to the plant disease problems and to the demands that are made upon the plant pathologist.

Forage and grain crops demand attention in the larger dairy centers where the soil type or topography is adapted to a pasture-hay-grain farming system rather than to cultivated crops.

Not only has New Jersey this immense variety of economic plants, which multiply the number of disease problems; her climate also adds to the trouble. Rainfall is usually abundant and often erratic, and even when rainfall is below normal there may be long periods of high humidity and heavy dews or fogs. These conditions frequently bring on severe outbreaks of diseases and make control more urgent and more difficult.

This combination of a great variety of economic plants, grown both intensively and extensively, along with a climate that is highly conducive to the development of various plant diseases, makes New Jersey a fertile field for the development of plant pathology. It would be expected, therefore, that plant pathology, both as a technical science and as a practical aid to solving plant disease problems, should have developed at a very early date in New Jersey.

DR. HALSTED--PIONEER PLANT PATHOLOGIST

Plant Pathology had its birth in New Jersey with the appointment of Byron D. Halsted as botanist in the New Jersey Agricultural College Experiment Station in 1889. Dr. Halsted was trained as a botanist, but his major interest for many years lay in the field of plant diseases. He was deeply interested in the applied side of botany, as is evident from the fact that some dozen of his earliest publications dealt with plant pathogens.

It must have been a welcome challenge for this pioneer plant pathologist when he was appointed to a position in New Jersey where plant disease problems were so numerous, so varied and of such economic importance. We see this reflected in Halsted's report written after his first summer in New Jersey: "The season just closed (1889) has been a remarkable one for the ravages of injurious fungi. All crops have suffered and some, especially those of fruits have been almost a failure." These heavy crop losses due to plant diseases and lack of information on methods of preventing them must have had a great deal to do with Dr. Halsted's decision to enter the field of plant pathology so seriously.

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[1] Paper of the Journal Series, New Jersey Agricultural Experiment Station, Rutgers University - The State University of New Jersey, Department of Plant Pathology.

The challenge to prevent these "ravages of injurious fungi" was accepted immediately, and for many years Dr. Halsted devoted most of his time and thoughts to the study of plant diseases. His greatest ambition was to solve the plant disease problems that were causing such severe losses in those early days when plant pathology was in its infancy.

During 1889 Halsted studied such destructive diseases as late blight rot of potatoes, black rot of grapes, leaf gall and fruit rot of cranberries, downy mildew of cucumber and rots of the sweetpotato. Disease control with fungicides was carefully studied and the use of bordeaux mixture was advocated for the control of various diseases. In subsequent years the field was gradually expanded to include a wide variety of crops such as miscellaneous vegetables, small fruits, tree fruits and a long list of ornamentals. These studies were so extensive that as many as thirty or forty different economic plant diseases were studied and reported upon in a single season. Nor were these studies superficial in many cases. For example, the club root disease of cruciferous crops, soil rot of sweet potatoes, common scab of white potatoes, fire blight of pears rust of asparagus, and numerous other diseases were carefully studied year after year, from the standpoints of etiology and of control. Many contributions of permanent value resulted from these early studies.

During the years that Dr. Halsted devoted his major attention to plant pathology a number of new diseases were discovered, studied, and accurately described, and the life histories of several important pathogenic fungi were investigated. Many of the better known diseases that were causing serious crop losses at the time were also studied in detail and control measures suggested. Numerous cross inoculations were made, particularly with Gloeosporium, to determine differences or similarities among several so-called species attacking various hosts. Many of these studies were of the utmost importance in leading the way toward later developments in the field of plant pathology.

With all of these detailed studies Dr. Halsted never lost sight of the ultimate aim of the plant pathologist: disease control. The effectiveness of copper fungicides, especially bordeaux mixture, in controlling numerous foliage diseases was tested repeatedly, and lime applications made to the soil were found to prevent club root of cabbage. He demonstrated that sulfur applied to the soil would reduce the losses from both scab in white potatoes and soil rot in sweetpotatoes. The value of seed treatments was also investigated, and certain treatments were advocated for cereals and other crops.

HALSTED RETURNS TO BOTANICAL STUDIES

It was a serious blow to plant pathology, and it must have been to Dr. Halsted himself, when failing eyesight finally forced him to give up the tedious microscopic studies that he so dearly loved and that he considered so essential to the progress of plant pathology in those pioneer days. He found other useful outlets for his boundless energies, however, and devoted his last years largely to studies in genetics and plant breeding. This transfer of interest from plant diseases to breeding began in 1898, and by 1900 most of Dr. Halsted's time was devoted to his new projects.

During the short period from 1889 to 1899, which Dr. Halsted devoted almost exclusively to pioneering work on plant diseases, he laid a foundation for plant pathology that was both extensive and solid. In Dr. Halsted, plant pathology had a far-sighted and energetic pioneer who not only blazed a clear trail but also opened many roads that led to practical plant disease control.

DEPARTMENT OF PLANT PATHOLOGY FORMED

This early work in plant pathology was a very firm footing upon which to build a special Department of Plant Pathology in New Jersey. This new Department was established in 1911, and Dr. Melville T. Cook, a graduate of Stanford University and holder of advanced degrees from De Pauw and Ohio State Universities, was appointed as New Jersey's first plant pathologist to head it. Dr. Cook was also appointed New Jersey State Pathologist, in charge of nursery inspection under the State Board of Agriculture.

The new Department of Plant Pathology under Dr. Cook's leadership grew rapidly and two assistants were appointed within the year. The destructive chestnut blight disease (Endothia parasitica) was at its height during these years, and Dr. Cook devoted much time to a detailed study of this dreaded disease. The virus diseases, yellows and little peach, which were threatening

New Jersey's important peach industry were included in the research program. Dr. Cook and his associates also continued the investigation on sweetpotato diseases, apple storage rots, and diseases of ornamental plants which had been started by Dr. Halsted.

During this period Carl A. Schwarze, who devoted his major time to nursery inspection, performed a lasting service to all future New Jersey plant pathologists by his monumental work of recording by careful descriptions and detailed pen drawings, some 350 parasitic fungi commonly found on economic plants in New Jersey.

Dr. Cook remained head of the Department of Plant Pathology from 1911 until 1923, when he resigned to become plant pathologist of the Insular Experiment Station at Rio Piedras, Puerto Rico. During these first twelve years, the Department had grown slowly but steadily, so that by the time Dr. Cook resigned it consisted of four full-time plant pathologists and several graduate assistants.

DR. WM. H. MARTIN BEGINS HIS LONG CAREER AS HEAD OF PLANT PATHOLOGY

With this staff as a nucleus Dr. Wm. H. Martin, who was appointed head of the Department to succeed Dr. Cook, further expanded the plant disease research program and gradually added three more members to the staff. It now includes seven full-time plant pathologists in addition to a fluctuating number of graduate assistants.

Under Dr. Martin's leadership the work of the Department was distributed among the staff members largely on a crop basis. From this time on, the plant pathology Department developed along specific crop lines with specialists in each field. Further discussion of this development will deal with crops rather than chronological events.

EXTENSIVE WORK ON POTATOES

Dr. Martin had served as potato specialist for several years under Dr. Cook. Before being appointed head of the Department, he had already made marked progress in the study of the numerous and perplexing disease problems affecting New Jersey's multimillion dollar potato crop. As head of the Department, Dr. Martin continued and even expanded this extensive research program on potatoes. First Graham Campbell and later John C. Campbell took charge of all the potato work under Dr. Martin's personal supervision.

A unique departure from the usual departmental duties was undertaken in connection with this potato program. Dr. Martin had originally been assigned to conduct all work on the white potato, regardless of whether it pertained to diseases or whether it was related in some other way to economic potato production. This arrangement permitted the development of an all-inclusive potato research program able to cope with any problem that seriously affected the potato industry.

In the earlier phases of these potato studies disease problems were of paramount importance. Scab was reducing yields and seriously impairing quality. Rhizoctonia was causing irregular stands and affecting both yields and salability of the crop. Late blight took very heavy tolls under certain conditions, and the foliage breakdown, popularly called "hopper burn", was a serious problem. In addition to these, several virus diseases were causing more and more trouble in the production of white potatoes for seed and threatened to destroy this particular industry.

One after another these troubles were eliminated as serious threats to the potato industry. In line with suggestions made by Halsted in his pioneering work, sulfur as a scab control agent was more carefully investigated and soon was successfully used to eliminate this disease as a major problem. Later by coordination of the fertilizer and disease studies it was found that the proper use of physiological acid fertilizers which tend to reduce the pH of the soil gave perfect control of scab. This simple method eliminated the need for special sulfur applications and avoided some of the objectionable features of the former method.

Years of work on Rhizoctonia have greatly reduced the losses caused by this disease. Experiments by the hundreds have been conducted during the last 25 years to determine the relative effectiveness of fungicides in controlling late blight and other foliage diseases. These have included comparative studies with numerous fungicide-insecticide combinations; comparison of dusts with sprays; studies on the relative value of calcium and magnesium limes when used in sprays or dusts; careful study of substitutes for bordeaux mixtures and of various organic fungicides; and numerous other studies related to spraying and dusting. As new insecticides were introduced or suggested as possible substitutes for the standard types in use at the time, these were included in the extensive field experiments.

Numerous laboratory, greenhouse and field experiments were conducted along nutritional lines. Studies were included on highly concentrated and other fertilizer types, plant food sources, minor elements, fertilizer placement and rates of application.

Experiments on depth of planting, seed-piece spacing, seed-piece size and varieties were included to determine under what condition highest yields might be obtained. Crop rotation systems, cover crops, and irrigation studies were added to this all-inclusive potato program.

In addition to directing these careful studies on potato problems that affect the New Jersey grower, Dr. Martin has led numerous national potato programs of importance. He worked hard and successfully to improve the potato seed certification program and to encourage the use of only certified seed by every grower. He has also aided the general potato industry by his long and efficient service as editor of the American Potato Journal. He may be given credit largely for the development of orderly marketing programs to prevent sharp breaks in prices during the peak of the harvesting season.

As a result of these years of coordinated research on diseases as well as production and marketing problems all cemented into a well-integrated general potato program, diseases and numerous other problems that formerly threatened the potato industry of New Jersey have been greatly minimized or eliminated entirely.

CONTROL OF FRUIT DISEASES

New Jersey's 35,000- to 40,000-acre apple and peach industry has received invaluable aid as a result of many years of continuous study of the numerous disease problems affecting these crops. Here the Department of Plant Pathology limited its studies largely to pathological problems, although nutritional studies have been included where these were associated with the incidence or with the symptom expression of the disease.

These orchard studies were started in the early 90's by Dr. Halsted. Around the turn of the century, fire blight of pears became a serious problem. Pruning tests were found to give some degree of control, but the twig blight phase of the disease was never wholly subdued.

When lime-free fungicides were introduced, another new problem arose on peaches. This trouble, which resembled a canker disease, was carefully studied and found to be a result of arsenical injury. Losses from this source were largely eliminated by 1925, although further studies on arsenical injury were conducted more recently by Dr. Robert H. Daines.

The economic importance of the fruit industry in New Jersey forced the plant pathology Department to conduct research on orchard diseases annually since Halsted's early work, but it was not until the appointment of Dr. Daines to the staff in 1930 that tree fruits received the attention they deserve. Dr. Daines has devoted a large part of his time to careful studies on the most effective means of controlling scab, fruit spot, black rot, bitter rot, cedar rust and fire blight of apples. Similar attention has been given to leaf spot of cherries and to brown rot, bacterial spot and canker diseases of the peach. As a result of these studies the most progressive orchardists are now growing fruit crops virtually free from major diseases and are able to compete with other fruit areas where disease problems are not so acute.

This very active fruit research program is still in progress, testing the various new fungicides as they appear and looking forward to continuous improvement of the costly spray and dust schedules necessary to produce a salable crop. Careful studies are also continuing on bacterial spot of peach and other diseases that have not yet fully surrendered to our control measures.

SWEETPOTATO DISEASES IMPORTANT IN NEW JERSEY

In addition to this fruit disease program, Dr. Daines has made notable contributions toward the solution of serious disease problems in sweetpotatoes. Sweetpotatoes have always been a very important crop in New Jersey, and losses from diseases are normally very heavy. Studies on this crop were started in 1889 by Dr. Halsted, and some progress in disease control was made in those early days. Dr. Cook himself continued the sweetpotato disease studies on a minor scale for a number of years until they were expanded into a major study by Dr. R. F. Poole from 1920 to 1926. Dr. Poole devoted the greater part of his time to this crop and made excellent progress before he resigned in 1926. After Dr. Poole's resignation the momentum of the sweetpotato studies was decreased for a time, but the most important projects were continued during the interim by Dr. Martin and various members of the staff. They were ultimately taken up as a major project again by Dr. Daines when Martin's administrative duties forced him to transfer some of his research projects to other members of the staff.

Under Dr. Daines, the sweetpotato work was further expanded to include several problems not studied in detail before. He continued the study on such sweetpotato field diseases as pox, stem rot, and scurf started by his predecessors, and in addition made extensive studies of plantbed diseases and sprout-borne diseases, as well as storage and transit rots. Marked progress has been made in the control of plantbed troubles; successful sprout dips have been developed which largely eliminate sprout-borne diseases; and outstanding results have been obtained in the control of sweetpotato rots that have caused heavy losses during the storage and marketing periods.

A borax dip was developed which greatly reduced the losses from decay during marketing. Even greater benefits have resulted from studies on storage methods. Years of study with a dozen experimental storage chambers, with both temperature and humidity controls, have resulted in specifications for commercial storages that are reducing rot and shrinkage to a minimum. The full effects of these studies will be felt more keenly as time goes on and as more storages are constructed according to these new specifications.

The benefits derived from the long years of studies that have been conducted on sweetpotato diseases alone have added millions of dollars to the economy of New Jersey's agriculture.

ORNAMENTALS HAVE RECEIVED MAJOR ATTENTION

The development of the ornamental branch within the Department of Plant Pathology in New Jersey has been epoch-making. New Jersey's immense investment in ornamental plants and the many plant diseases that threaten these investments have caused continuous pressure on plant pathologists for more and more information on how best to protect lawns, shade trees, greenhouse and nursery stock and other ornamentals from losses due to diseases. Dr. Halsted keenly felt this pressure as soon as he arrived in New Jersey and did a great deal of work on diseases of ornamentals in the early nineties. Dr. Cook continued these studies in a minor way, and various other members of the plant pathology Department were delegated from time to time to investigate problems of immediate importance. These earlier studies were of an emergency nature, however, and were never developed to the extent that the investment in ornamentals warranted.

The need for expanding the research program on ornamentals finally became so urgent that in 1927 Dr. R. P. White was appointed to devote his entire time to the study of disease problems of ornamental plants. Dr. White continued these studies for eleven years, until he resigned to become executive secretary of the National Association of Nurserymen. During those years Dr. White worked on a variety of disease problems affecting ornamental plants, including roses, gladioli, ericaceous plants and many others.

Dr. P. P. Pirone took over the study of ornamentals where Dr. White left off also devoting his entire time to this field. He continued investigation of a long list of nursery, florist, shade tree and lawn problems until 1947, when his wide experience drew him to the New York Botanical Garden staff. After a short lapse of time enforced by the scarcity of men trained in pathology of ornamental plants, disease work in this special field in New Jersey was taken over by Dr. Spencer H. Davis, Jr. in 1948. Dr. Davis devotes full time to this large and important group of plants, as did his two predecessors.

VEGETABLE DISEASES IMPORTANT IN THE GARDEN STATE

Vegetable production is another very significant branch of agriculture in New Jersey. The development of an extensive research program for this large group of plants is to be expected in a State that boasts the title of "The Garden State." Some half-hundred vegetable crops are grown commercially in New Jersey, and each is attacked by one, or sometimes a half dozen or more, diseases of considerable importance.

The vegetable disease studies, like so many others, were begun in 1889 by Dr. Halsted. They have been carried on without interruption since that time. From 1922 to the present time these studies have been made largely by Dr. C. M. Haenseler, assisted in recent years by Dr. B. H. Davis. Because of the large number of vegetable problems calling for attention in New Jersey, most of the efforts have been directed toward development and improvement of control measures. Less attention has been given to technical studies on etiology and to detailed studies of life histories or physiology of the pathogens. Careful attention has been given to such important diseases as anthracnose, early blight and late blight of tomatoes; mosaic and bacterial leaf blight of peppers; root rot of peas; club root of crucifers; wilt and fruit rot of eggplants.

Virus yellows of lettuce and bacterial wilt and smut of sweet corn have also received careful attention.

In cooperation with the entomology department, a satisfactory control measure for lettuce yellows was developed and its was also found that ear smut of sweet corn, which sometimes destroys 30 to 60 percent of the ears of certain varieties, could be greatly reduced or almost eliminated in some cases by the use of certain insecticidal dusts.

Studies have been conducted on problems that affect vegetable crops in general, such as seed decay, damping-off of seedlings, miscellaneous plantbed diseases and root knot nematodes.

In addition to these major studies, numerous other disease problems which occur only spasmodically have been added to the vegetable disease research program from time to time. A few outstanding examples of such spasmodic outbreaks of diseases which cause little trouble in the average season are as follows: asparagus rust in 1896-97 and again in 1924 and 1936; bacterial wilt of sweet corn from 1928 to 1933 inclusive; bean rust 1936-38; and late blight of tomatoes 1946-48. In each of these periods special emergency studies were conducted on the specific diseases.

A detailed survey of the vegetable disease studies conducted in New Jersey alone since 1889 would give a graphic picture of how numerous, how varied and how important phytopathological problems can become in a small area.

CRANBERRY AND BLUEBERRY DISEASE STUDIES

Plant disease studies on cranberries and blueberries in New Jersey developed somewhat independently of the Plant Pathology Department, yet these projects are of such importance that they deserve to be recorded here. Since the beginning of the studies on cranberry and blueberry diseases, the major part of the work has been done at a branch station at Pemberton in the vicinity of bog areas. The extensive disease studies at the Cranberry-Blueberry Station were conducted almost in their entirety by the late R. B. Wilcox, who was assigned by the U. S. Department of Agriculture to cranberry and blueberry work in New Jersey. Wilcox did monumental work on control of false blossom and fruit rots of cranberry and on the virus "stunt" and other diseases of the high bush blueberry. The false blossom virus disease of cranberries might have doomed this crop had it not been for the study of the vector and the consequent development of control measures by Wilcox. His great progress in breeding cranberry varieties resistant to false blossom is also noteworthy. This work will bear fruit for many years to come.

AIR POLLUTION WITH PHYTOTOXIC FUMES

In addition to the disease problems that receive attention year after year, emergency cases occasionally arise which demand prompt and careful investigation by the pathologists. Some of these become perennial problems also and are added to the regular studies. Such a problem arose some years ago when phytotoxic industrial fumes were released in damaging quantities in the vicinity of New Jersey's important agricultural areas. Demands for information on the cause and extent of these injuries and for corrective measures brought a new line of research to the plant pathology Department. It was soon found that fluorine was most probably the menacing chemical. Since little information was available on the subject, a special fundamental research program was developed to obtain information on all phases of the fluorine plant-injury problem. Dr. Daines was placed in charge of this project, and several chemists and members of other departments have assisted in various phases of the work.

These studies on fluorine recently aided farmers greatly in obtaining reimbursements for damages caused to their crops by fluorine gases. They have also been instrumental in hastening the installation of industrial safeguards which should greatly reduce the danger of crop loss from similar sources in the future.

DEVELOPMENT OF NEW FUNGICIDES

Another significant chapter in the history of plant pathology in New Jersey deals with the development of new fungicides. A great deal of attention has been given by every member of the department to the evaluation of various new experimental and proprietary fungicides as they have been proposed or placed on the market. Such studies are necessarily conducted on each important crop and in every major climatic area before definite recommendations can be given. In addition to this herculean task of evaluation of known fungicides and of determining where and how each can best be used in practical plant disease control, the Department of Plant Pathology has played an important role in the development of new fungicides.

The first far-reaching step in this field was made in 1915 when Prof. A. J. Farley began trials with lime-sulfur-glue mixtures as substitutes for self-boiled lime sulfur, the spray material commonly used on peaches at that time. After further improvement and modification of these lime-sulfur-glue mixtures, Prof. Farley, in 1923, introduced "New Jersey dry mix" a simple formulation containing sulfur, lime and calcium caseinate. This mixture could be mixed dry, stored in bags and added directly to water to make an effective, easily applied fungicide for use on peaches and other stone fruits.

The introduction of "New Jersey dry mix," the first of the so-called "wettable sulfurs," was followed by various other types of "wettable sulfurs" which have totally replaced the original self-boiled lime sulfur so popular before 1923.

The next big step taken by New Jersey in developing new fungicides was Dr. Alwyn Sessions' introduction of "Coposil." This copper silicate fungicide was developed in the Department of Plant Pathology from 1929 to 1933 in response to the current need for a copper fungicide that was miscible with oils and safe to use on pomaceous fruits. "Coposil" was the first copper fungicide developed since the discovery of bordeaux mixture between 1882 and 1885 that has been used on a large scale. The introduction of "Coposil" seems to have been the spark that touched off a series of research studies which finally resulted in the development of such fungicides as the copper oxides, basic copper sulfates, copper oxychlorides, and copper oxychloride sulfates.

In recent years the Department of Plant Pathology has continued its interest in new fungicides. It has biologically "screened" hundreds of chemicals in search for compounds with outstanding fungicidal properties and low phytotoxicity.

This tedious search has yielded a new product with high toxicity to fungi and low toxicity to higher plants and animals. This recent development, announced late in 1949 under the laboratory number SR 406, has given marked success in the control of many plant diseases both in America and abroad. It may prove to be the third notable forward step made by New Jersey in the steady march toward new and better fungicides.

EXTENSION IN PLANT PATHOLOGY

In the field of agricultural extension, plant pathology in New Jersey has developed along somewhat hybrid lines. No extension specialist in plant pathology has ever been appointed in the State, although this does not mean that plant pathology has not received due attention by the extension division.

Through his 40 years of contact with fruit disease problems in New Jersey, Prof. A. J. Farley, extension specialist in horticulture, has become an expert practical fruit pathologist. He has devoted the major part of his thought and time to problems confronting New Jersey's apple and peach industry and has been largely responsible for the effective job New Jersey fruit growers are doing in producing disease-free fruits. It is largely due to Prof. Farley's long years of contact with the fruit growers and his thorough understanding of fruit disease problems that the New Jersey grower is so well informed on the major diseases and the latest methods of control.

Charles Nissley has followed a similar course as extension specialist in vegetable production during the 32 years that he has held this position. Since diseases have always caused serious losses in vegetable crops in New Jersey, it has been imperative that the extension specialist give disease control a prominent place in each year's program, and Nissley's long contact with vegetable problems has given him a thorough knowledge of the many diseases of vegetable and truck crops that occur in the State.

Excellent work in the practical solution of disease problems affecting small fruits and vine crops, especially strawberries, raspberries, and grapes is also being done by Ernest Christ, the extension specialist in pomology. All this work is conducted in the closest cooperation with specialists in plant pathology.

In addition to these crop specialists in the extension division who have been distributing information on plant diseases to New Jersey growers for so many years, there was appointed in 1949 an extension specialist in entomology, the first such appointment in the State. Although his official title is extension entomologist, this specialist is devoting some of his time to plant disease problems.

CLOSE COOPERATION AMONG PLANT PATHOLOGISTS AND OTHER SPECIALISTS

The lack of an extension specialist in plant pathology in New Jersey who devotes full time to disease control has been a handicap in some respects, yet it has had its beneficial effects also. It has forced the various research plant pathologists to allocate portions of their time to duties of an extension nature. Under this system, the extension phases of plant pathology have not suffered so much as might be expected. And in many ways it has proved advantageous in that it has kept the research pathologists in intimate contact with the practical disease problems that were most urgently in need of solution at the time. This has had a tendency to focus most of the plant disease research program on applied phases of the science rather than on more fundamental technical problems.

There is another phase of the plant disease work in New Jersey that has developed as a direct result of the lack of a large staff of plant pathologists. Since such a small research staff is unable to cope with all of the important plant disease problems that need attention, many cooperative projects have been pursued with other departments interested in problems in which plant diseases play an important role.

Some very important results have been obtained through these cooperative efforts. As examples we may point to the improvement of varieties through breeding and to the development of improved methods of turf disease control. Breeding programs conducted by the Vegetable Crops Department have resulted in such successful varieties as the world famous Rutgers tomato and the mosaic-tolerant World Beater #13 pepper.

The successful breeding program conducted on fruits by the Horticultural Department has likewise resulted in the introduction of numerous noted varieties of peaches as well as several varieties of strawberries that are virtually immune from the red stele disease. These breeding programs received close cooperation from plant pathologists in developing the degree of disease tolerances that these varieties possess.

Cereals and field crops have received little attention from disease specialists in New Jersey. But here also many research projects on small grain, corn, and hay crops have included disease studies through cooperation between the plant pathologists and the field crop specialists in charge of the work. Breeding work on alfalfa with resistance to bacterial wilt as one of the major objectives, and the development of hybrid corn, with resistance to stalk rot in field corn and to bacterial wilt in sweet corn as important factors, are examples. Success in these projects has been aided materially by the cooperation of trained plant pathologists.

With this intricate relationship between plant pathology and various other branches of agricultural research, the influence exerted by the plant pathologists in New Jersey has reached far beyond the specific major research studies conducted by the pathologists themselves. Much has been accomplished by this whole-hearted cooperative spirit that permeates the Plant Pathology Department. The Department's policy has always been to help in every way possible where plant disease problems are involved.

THE STATE DEPARTMENT OF AGRICULTURE: ITS ROLE IN PLANT PATHOLOGY

A discussion of the development of plant pathology in New Jersey would not be complete without some mention of the important role played by the State Department of Agriculture. The State Department is responsible for the regulatory work pertaining to plant diseases and for such eradication measures as may be required from time to time. It is also in charge of seed certification and nursery inspection, programs that have tremendous effects on the disease problems of specific crops.

SEED CERTIFICATION BY STATE DEPARTMENT OF AGRICULTURE

Freedom from seed-borne diseases is a major item in the specifications for seed certification Where seed-borne diseases are an important factor in economic crop production an effective seed certification program has far-reaching results in disease control. The importance of the seed certification program in New Jersey is illustrated by the volume of tomato seed production alone. The 10-year average production of New Jersey certified tomato seed from 1939-48 was approximately 76 tons annually. An all-time high was reached in 1947 when more than 146 tons of certified tomato seed was produced. This is an immense volume for a crop that takes so little seed to plant an acre. It is easy to conceive what could happen if this huge quantity of seed, which is sold all over the world, lacked the protection against seed-borne diseases that is provided by certification.

Barley, soybeans, corn, and potatoes intended for seed also come under the careful scrutiny of the State Department's seed certification program. In these crops the grower is provided with a source of seed that should give the minimum hazard from diseases due to seed-borne pathogens.

QUARANTINES AND DISEASE ERADICATION BY STATE DEPARTMENT

The State Department is charged with the duty of enforcing quarantines that restrict the movement of specific diseased material considered dangerous from standpoint of plant disease control. It may also be called upon to eradicate newly introduced diseases as it was when the Dutch elm disease threatened to destroy the American Elm. In this case a very extensive program, conducted in cooperation with the Federal government, was undertaken in a desperate effort to eradicate this destructive disease while it was still confined to a relatively small area. Many thousands of infected elm trees were destroyed in an attempt to exterminate the causal fungus or effectively to reduce the population of the insects that transmit the disease. Although these attempts were not wholly successful, similar alertness and enthusiasm on the part of the State Department in the early eradication of some other newly introduced diseases may pay untold dividends.

It is worthy of record that all phases of plant disease work done by the State Department of Agriculture is undertaken after consultation with plant pathologists at the State University and Agricultural Experiment Station. This close cooperation among regulatory agencies and the research specialists has been a great help in establishing and maintaining a uniform plant disease control policy in the State. All branches of the State that deal with plant disease problems, whether they relate to research, extension, formal education, or regulatory work, have the same general viewpoint and work in harmony toward a common goal.

TEACHING IN PLANT PATHOLOGY

A final branch of plant pathology as it has developed in New Jersey deals with formal training of students in the subject of plant diseases and methods of control. The Department of Plant Pathology at Rutgers University has taught formal courses in plant diseases for more than a third of a century. During the first few years of this period, only undergraduate courses were available to the student. Later, advanced studies leading to the degrees of Master of Science and Doctor of Philosophy, with majors in plant pathology, have been offered.

Every college student majoring in fruit or vegetable production is required to take a fundamental course in plant pathology. More advanced courses are available for those undergraduates who need more specialized training in this field. Further specialization both in class and research is available for students desiring to enter the field of plant pathology as a profession.

In addition to this fundamental and detailed training in plant pathology given to full-time college students, Rutgers University also offers numerous types of "Short Courses" in plant diseases to special groups. These vary from 3- to 5-day intensive courses on plant disease problems for groups with highly specialized interests, to 10- or 12-week formal "Short Courses in Agriculture" for adult students who wish to study agricultural problems in general.

These various courses in plant pathology, given to both full-time and part-time students in Rutgers University annually, have had a far reaching effect on the gross plant pathology picture in New Jersey. Many of the leading farmers have had brief but intensive formal training in plant diseases. They are therefore well equipped to function as effective agencies for distribution of reliable information on plant disease control within their community. Most of New Jersey's county agricultural agents, vocational agricultural school teachers, club agents and other leaders who come into intimate contact with farmer groups have received more or less detailed instruction in plant diseases and plant disease control. True, these various leaders are far from professional plant pathologists, but they do have a sufficiently broad training to act as reliable agents for dissemination of the latest information on plant disease control.

The benefits derived from this widely scattered group of community leaders who have had some training in plant pathology is more and more obvious as the years go by. Improvement is not always evident from one year to the next, but from decade to decade, or even shorter intervals, marked advancement can be seen. As a result of this gradual improvement, the average New Jersey farmer today approaches his plant disease problems with a much better understanding of the principles involved in disease control, and therefore with better assurance of success, than ever before.

We may attribute this improvement largely to the persistent educational work done by extension agents and local leaders familiar with the general aspects of plant pathology. And we may in turn attribute the success of these workers largely to the formal training in plant pathology that they themselves received at the university.

PLANT DISEASE SURVEY

One of the weakest links in New Jersey's plant disease program is in recording the occurrence and relative importance of plant diseases. Through the diligent efforts of Dr. Elizabeth S. Clark, Assistant Plant Pathologist, the department has fairly complete records for over 20 years of all plant diseases sent in for identification or reported by various other members of the department. These records are of the greatest value but they are not sufficiently complete to reflect the true significance of the various diseases.

There has been no careful survey for the specific purpose of recording all plant diseases that occur within the State and consequently many of the minor diseases still remain unreported from

New Jersey in official lists giving disease range.

The research, teaching and extension staffs have been so occupied in assembling and distributing urgently needed information on the major disease problems that the project on disease survey has been somewhat neglected. A more elaborate program of estimating crop losses caused by diseases and of recording the presence and prevalence of diseases annually is greatly needed. The addition of a strong and well-planned disease survey to the other branches of plant pathology in New Jersey would round out the program so that it should be well-equipped to deal with all the major disease problems occurring within the State.

MORE WORK YET TO BE DONE

This long-uninterrupted growth of plant pathology in New Jersey, from 1889 to the present, impresses us with the truth of Dr. Halsted's original contention that plant diseases in New Jersey are major items in economic crop production and that they deserve the most careful study. Since Dr. Halsted's pioneering days, many of the serious diseases have yielded, either partly or completely, to the advancing science of plant pathology. Much has been done in the past, but much remains to be done in the future.

The battle of plant pathology is by no means over. The need still exists for more effective and more economical control measures for most of our common diseases; there are ever-increasing demands for varieties resistant to specific diseases; and there is a crying need for more practical methods of controlling virus diseases, which are becoming more and more troublesome. New disease problems are sure to rise from time to time in the future. They have done so in the past and we have every reason to believe that they will continue to increase both in kind and importance in the years ahead.

New Jersey looks upon her past development of plant pathology with due pride, but she is ready to admit that serious disease problems still exist and that even more serious troubles may be lurking in the future. She plans, therefore, to continue the steady march forward in plant disease studies, building further on the broad base that has proved so firm in the past, that is, research, extension, teaching, and regulatory activities, all working in close cooperation and directing their efforts toward a common goal -- the most economic control of plant diseases.

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